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NOTICE.

Discussion or further discussion by members on any of the articles of this number will be printed in the next issue of the Proceedings. Any such matter should be in the hands of the Secretary by December 10, or as soon thereafter as practicable.

J. H. GLENNON, *Secretary and Treasurer.*

THE PROCEEDINGS

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HONORABLY MENTIONED.

MOTTO: SIMPLICITY.

SUGGESTIONS FOR INCREASING THE EFFICIENCY OF OUR NEW SHIPS.

By NAVAL CONSTRUCTOR WM. J. BAXTER, U. S. Navy.

The warship of to-day is the most wonderful product of the fertile brain of man; the skill of every art, the theory of every science, and the practice of every trade have contributed to its development, while for its efficient use a special talent of the highest order is necessary. It is an arsenal, a fort, a magazine, a drill ground, a training school, a storehouse, a bank, a workshop, a hotel, a barrack, a hospital, a machine, a church, a prison, a home; but above all it is a unit of sea power, a floating weapon controlled by one man for offense and defense. Like other weapons it should be ready for use at any moment, success depending on skill and bravery alone. Practically, however, this weapon is called upon to perform such numerous and varied functions that it has become a honeycomb structure filled with complicated mechanisms, traversed in all directions by a labyrinth of pipes and shafts, and crowded with scientific appliances and

intricate fittings, all of which are liable to such derangement and wear that continual repairs are necessary; and it is subject to sudden and unforeseen mishaps which may happen every time the anchor is weighed. The captain cannot now supervise and direct every part or fitting, he must trust more than ever to the skill of his personnel and the reliability of his matériel: but the latter is so complicated and delicate that a personnel of many specialists is required merely for its efficient care and manipulation in peace. The naval officer is not a scientist and specialist, it is his high privilege to understand and use the developments of science and mechanics which are suitable for his purpose. If the appliances furnished him are so intricate as to require a long and special study of each one, he is apt to be lost in a mass of details and and overlook his larger duty of using these appliances merely as instruments which are to be combined in the best manner to produce the most efficient weapon. The crew are far from being specialists, they do not even understand the use of many of the devices about them, and are ignorant of how to take care of them; yet ignorance or negligence is more quickly fatal now than ever before. Every portion of the warship and her equipment should be adapted to secure efficiency with the men available: the human factor cannot be neglected. Any part which saves weight at the expense of durability, which saves space at the expense of accessibility, or which is automatic at the expense of simplicity, is out of place on this floating weapon; no matter how successful it may be elsewhere. The many ingenious appliances and elaborate fittings which crowd our new ships, though worked out with the greatest care, are a source of weakness if they are unnecessary, or if they are not adapted to the trying conditions of service usage. The more simple and durable the ship and her equipment, the greater will be the efficiency, for the crew can become familiar with the use and care of every appliance, and there will be less liability to derangement in excitement or danger.

Mahan has shown us that good men with poor ships are better than poor men with good ships; it is our duty not only to secure and keep the best men, but to secure the best ships and to train the men in preserving and using them, to follow the service tradition of having the personnel and matériel of each ship superior to any foreign ship of the same rate. This is thoroughly

realized by every one in the service ; and in the building, equipping and manning of the new ships there has been universal interest ; and naturally there was pressure from all sides to make them superior to their foreign competitors in every quality, for each one is apt to think that the quality to which he had given special attention and study was of particular importance. It is therefore not surprising that simplicity has been lost sight of, and that the trying conditions of service afloat were overlooked in the quiet of shore study.

The best warship is the one which most harmoniously combines armor, armament, speed, handiness, habitability and sea efficiency, and which permits the best use of this combination as a whole by the personnel available. The more limited the purpose of this ship the better will be the combination for the end in view ; no one quality, however, can be magnified except at the sacrifice of one or all of the others, the lack of which will surely be felt at some supreme moment. In the commendable desire to secure perfection in every quality, have we not lost sight of the prime importance of securing efficiency in the ship as a weapon ; and, in the unrealizable desire to fulfill all conditions, so sacrificed simplicity that this weapon is now so complicated as a whole, and so crowded with delicate equipments, that there is too great a liability of derangement or break down from ignorance or negligence?

The ship's efficiency depends upon the certainty that the essential qualities are available when wanted ; if they are obtained by intricate and delicate appliances which function properly only on the proving ground or in the workshop when manipulated by skilled mechanics, there is no certainty that they will be reliable at sea when really needed. In the old ships, officers and crew had that special knowledge which came from long sea experience with familiar equipments, but to-day they spend much of their time in port, and the equipments vary with every ship.

This state of affairs being brought about by the demands of the service, its improvement and remedy lies equally with us ; but it can only be brought about by *l'entente cordiale* which sees the necessity of sacrificing some pet scheme in order to secure greater efficiency of the whole ship. It is difficult to overcome the tendency to exaggerate the necessities of the present moment, and thus forget the possible contingencies and catastrophes of the future. It can only be done by bearing in mind that simplicity

requires that everything should be discarded which is not necessary to the efficiency of the weapon or to one of its essential parts, and that nothing should be added unless the advantages of its presence more than counterbalance the disadvantages of its absence.

We are all too apt to believe that while great reforms are necessary in another's arrangements, our own need only some slight additions to make them perfect. Yet, if all the suggestions were summed up, it would appear that complication and crowding were absolutely necessary; that the ships of to-morrow must be even more complicated than those of to-day; that perfection will only be obtained when a vessel shall be produced which shall contain all known means of offense and defense and all known appliances for economy, comfort and convenience. The followers of this school doubtless believe that in time the warship should be like the popular slot machines, when the captain automatically presses a button the vessel will do the rest; do they ever consider what will happen if the button fails to work?

The sciences of peace should not overshadow the science of war, on the warship.

This is not said in a reactionary or conservative spirit, nor to proclaim the failure of what has been done, nor to criticize in any way the faithful work of those thoughtful officers whose combined ingenuity and study have produced the ships of which we are so proud; but it is no reflection on any one to say that there is still room for improvement.

The writer is convinced of the immense importance of simplicity, and he believes that, without any reduction of the fighting power, or any lessening of those comforts which are necessary for the health and cheerfulness of officers and men, more efficient ships will result from the adoption of simplicity as the ruling principle of design and organization. There is nothing novel in this idea, and numerous authorities could be quoted; the following, however, expresses the thought very clearly.

Jurien de la Gravière says: "Les idées simples ont toujours quelque peine à prevaloir. Quand l'heure critique arrive, c'est infailliblement à elles qu'on a recours. Le pédantisme technique ne resiste pas à quelque jours de campagne."

Hichborn says: "The warship of our day has become far too complicated for the people who may be called upon to work her;

a balance of advantage, unsuspected by many, rests with that vessel which has comparative simplicity."

Simplicity does not mean an entire return to manual power, although the time will never come for its abandonment; it does not mean that every mechanism or appliance should be so simple as to be used or cared for by the merest landsman; nor does it imply that the fittings which increase safety and health should be discarded. But when for any safeguard supplied, another is crowded out or rendered useless; when one appliance must be accompanied by others to provide for the possibility of a break-down; when the hull requires such constant attention for its care and preservation that there is but little time for drill; when the motive machinery has the delicacy of a watch; when the decks are crowded with encumbrances of all kinds which obstruct the use of the battery and its supply of ammunition, or which render the crew uncomfortable and discontented; when the crew is composed mainly of specialists who know little else than their own particular duties;—when all this is the case, is it not time to remember that the warships exist only to carry guns, and that the officers and crew exist merely to fight them?

Our service is particularly fortunate in combining within itself those qualities which produce improvement; it is renowned for its knowledge of mechanical contrivances, and it has avoided the error of embodying all knowledge in one class of officers and all experience in another. Mere knowledge is insufficient; experience is absolutely necessary to produce the best results, as it gives insight into the causes of failures. Many fittings look well on paper, and even function well in the hands of their builders, which fail when used by those who have not the specialized skill required for their manipulation; and it often occurs that appliances which are satisfactory on shore are found to be entirely unsuited to service conditions afloat. In the difference between the grumbling statement of one officer that a certain part of the ship's equipment is "no good," and the intelligent report of another which states the circumstances of the failure, the probable reasons, and suggests a remedy, lies the key-note of successful improvement; one is mere experience, but the other combines knowledge with experience.

The happy union of these two qualities is especially desirable when considering the value of a ship as a weapon. Invention

should receive constant encouragement, but the inventive faculty, unless guided by experience, may run riot and produce a chaotic jumble which shall be defective as a whole, even though there may be no marked defect in any particular fitting. The electric light, the bicycle and the sewing machine are familiar examples of improvement brought about by simplification; those parts which are unreliable, or superfluous, are altered or discarded, and the result obtained by other means in a more satisfactory manner, after close study of the actual conditions of service. The warship of to-day is a new invention, for each one is a new combination of many inventions, and it can be improved in utility and reliability only by the combined efforts of those who build it and those who use it.

Familiarity with the behavior and performance of the ship under all conditions is the best way to ascertain the defects and their causes; and experience in remedying many defects of the same nature, developed under different conditions, is the best way to determine upon the improvement which will be most efficient in all cases.

At the close of the Civil War naval personnel and matériel were extraordinarily efficient because activity and invention were stimulated by necessity, and restrained by knowledge of the actual conditions of war service. The lack of any extended knowledge of naval warfare with modern warships emphasizes the importance of continual practice under conditions resembling those of war, to discover the good and bad qualities of each ship, so as to manœuvre and fight her to the best advantage in action, as well as to determine the best solution of the many problems still unfathomed for lack of experience. War efficiency is of the highest importance, but it is also essential to check unnecessary and wasteful expenditure, and to promote economical administration. The first cost of mere peace fittings is very great, and the expense of their repair often exceeds that of the essential fittings. They are also hurtful in their effect on the ship's discipline, as the crew become accustomed to refinements and conveniences which must be lacking in active service, and a spirit of fastidiousness in unimportant details is developed which exaggerates their importance, and fosters the habit of thinking that the ship is not ready for sea merely because some minor fitting is incomplete or unsatisfactory. While

it is necessary that every part of the ship's equipment should be so perfect that there will be small chance of derangement when it receives reasonable care, and so simple that the repairs due to ordinary wear and tear can be made by the ship's force; it is equally necessary to cultivate a spirit of responsibility and self-reliance, and a desire to remedy the innumerable small defects which are sure to occur, without the aid of a navy yard. If the crew do not feel the responsibility of making good all ordinary defects, due to service use or to casualties, a spirit of recklessness quickly appears, the ship becomes less efficient and the money paid for such repairs is an inexcusable waste. It is of still greater moment to prevent this, because preparation for battle in the most speedy and precise manner is a requisite for success; if the crew is so helpless as to depend on outside help in the most trifling matters, what can be expected in the hurry and excitement of such a time? Even when the crew is skilful and well trained, the time required for repairs must be taken from that belonging to drill or recreation, so that there is every reason for omitting all unnecessary fittings.

Mahan says: "Theories about the naval warfare of the future are almost wholly presumptive." But he also says, in speaking of England's policy in the Napoleonic wars: "She obtained the double advantage of keeping the enemy under her eyes, and of sapping his efficiency by the easy life of port, while her own officers and seamen were hardened by the vigorous cruising into a perfect readiness for every call upon their energies." We do know, however, that the war of the future will come unexpectedly, and that unless the ships are efficient and the crews are familiar with the means of offense and defense they contain, the ablest strategy and the most brilliant tactics will be of no avail. In view of the lack of both money and men, it will doubtless be necessary when all of the new ships are completed, to establish a class of ships in reserve which shall contain the mere nucleus of a crew, and as many small ships will be required for detached service and duty on foreign stations, this reserve will naturally be composed mainly of battleships, coast defense vessels and the larger cruisers. When mobilization for war service becomes necessary, these ships will be needed at once and the few men who know the ship will

be lost amidst new recruits. In such emergencies, the ships will be manned mainly by those accustomed to merchant ships and those who have had no experience afloat, and it will be fortunate if the great guns and main engines are used without casualties. We have only to read the accounts of foreign naval manœuvres to be impressed with the many casualties happening to machinery, boilers and steering gear and the numberless break-downs of minor appliances. When such things can happen in times of peace with other navies having a large number of trained men in reserve, and with sufficient warning to navy yard authorities to ensure the matériel being in fair condition, what can we expect with our limited navy yard facilities and the entire absence of any trained seamen? We have the volunteer Naval Reserve whose bravery and ability are unquestioned, but their experience cannot be sufficient to enable them immediately to manage the complicated mechanism of our new battleships. Hollis says: "At present it takes from six month to a year after a new ship goes into commission to get the best results out of her machinery; and through no fault of the firemen. It is only that they do not know when first taken on board." When this is the case is not some simplification necessary?

The necessity for rapid mobilization is but one of the many arguments in favor of simplicity, especially on large vessels. The captain manœuvring such a ship in action can no longer inspire the crew by his presence, he will not even know a tithe of what is occurring in the complicated structure he is directing, and even if he did he could not be certain that his orders were correctly understood and promptly obeyed. More than ever before will the issue depend on the nerve, judgment, and skill of the captain, and on the training, discipline and staunchness of the crew. Cannot a greater efficiency be obtained by making the ships less complicated, so that when the unfortunate necessity arises of fitting them out in haste, the essentials can be quickly mastered, and the crew can feel that, although they may be exposed to more danger from the enemy, there is less probability of danger from some act of ignorance or negligence of their own? The question of manning must be recognized.

In times of ease and leisure, elaborate and complicated methods of the completest character are a fascinating study, but in times

of action and pressure the simplest methods will be used. If the battleship cannot be made invulnerable and unsinkable except by intricate and delicate means which may fail in the hour of trial, it is surely better to secure simpler and more reliable means of offense and defense, and accept the risks ensuing from the absence of complicated refinements; or, to use Farragut's words, "The best protection against the enemy's fire is a well directed fire from our own guns."

One other reason for simplification: many methods for evaluating the fighting powers of warships in comparison with others of the same tonnage have been proposed, but as their different authors assign different relative values to each element of offense and defense, it is not to be expected that there will be agreement. The actual values of each element, however, tend to equalize themselves more and more; in guns, armor, machinery, torpedoes, subdivision and the like, the knowledge of what each navy is doing is so accurate, and the competition is so keen, that it is probable that real superiority of matériel will lie in simplification of detail. Between two ships equal in all other respects, the one which has the more simple matériel will be the more efficient, because it is not so easily or quickly deranged, and therefore the crew of that ship will have more confidence in her performance; their courage will be increased by knowledge of every resource, and many daring and unthought of expedients can be used with success.

Soley says: "The primary object for a navy at all times is to maintain itself in all its branches, matériel, personnel and organization in the most perfect state that is possible of readiness and efficiency for war." When any one feels that a greater degree of readiness and efficiency is possible, it is his duty to point out apparent defects and to suggest some remedy, leaving to higher authority the determination of the merit and practicability of his ideas. Every innovation is followed by unexpected consequences, and many objections can be raised against every suggestion offered; but when the service shall see that the defects due to complication have arisen from its own demands for perfection in every direction, further departures from simplicity and economy will cease. It matters little who furnishes suggestions for each improvement in the future, so long as there is a concensus of opinion as to their desirability.

In such a paper as this the treatment of the many branches of the subject must necessarily be sketchy and incomplete.

Standardizing is the most obvious means of securing simplicity. When the use and care of standard appliances and fittings are once learned, there will be less loss of efficiency when officers and men are transferred from ship to ship, and on foreign stations extensive repairs can be made by making good the defective parts of one ship from the surplus stores of another.

Standardizing reached its highest perfection at the opening of the century, when ships of the same rate were practically alike from keel to truck. During the long cruises of that period the crews became so familiar with every part of the equipment, that its use and care became almost an instinct. Extraordinary results were accomplished: the marvelous repairs to the Vanguard, and the skill displayed by the new crew of the Constitution, are familiar examples.

Conditions are now different, for the rapid progress of naval science quickly renders obsolete the fittings which were thought to be satisfactory. Too much uniformity will result in mere routine and discourage invention, but standardizing could safely be carried further than has been done. The lack of uniformity is largely due to the many rival ideas among ourselves, but this can be obviated by deciding on the fitting that is best suited for a particular purpose, and then continuing its use, even if it prove deficient in some respects until it becomes clearly obsolete. We have now had sufficient experience with the new vessels to extend the standardizing so admirably begun with ordnance and electrical fittings to many other parts of the ship's equipment.

The question of design is too large for consideration; but it is worthy of note that all navies have strayed too far from simplicity in one respect. In the effort to satisfy all demands and combine on small ships high speed, powerful armament and great protection, there has been such a great sacrifice of strength, stability, habitability and coal endurance, that efficiency as a whole has been lessened. To combine all these qualities in the best manner, there is no longer any doubt that large and costly ships are required: with small ships, some qualities are now deliberately sacrificed to secure reliability in others, as the necessity for simplicity is better understood.

Subdivision is a necessary departure from simplicity, its function being to prevent or delay capsizing or foundering; practically its value is vitiated by the necessity for piercing water-tight bulkheads and decks with doors and other openings, and pipes of all kinds. The Admiralty minute concerning the loss of the Victoria states that had the water-tight doors and hatches been closed, the ship would have been saved, but unfortunately it took from three to four minutes at the best to close them and the signal to do so was not given until one minute before the collision. The foundering of so many Chinese ships was probably largely due to the failure to close the doors by crews not properly trained. The difficulty of communication between the various parts of the ship and the great inconvenience ensuing when the doors are closed causes both officers and men to prefer the risk of foundering to the remedy. A certain number of doors must be kept open in action or fleet manœuvres, for the supply of ammunition and the control of the ship; but this is a necessary risk, which is minimized with a crew well trained to close them in an emergency. The danger lies with doors supplied for convenience and accessibility; even though they be reported closed, there is no surety for their remaining so during a panic. Simplicity demands that their number should be the smallest possible consistent with efficiency, at the sacrifice of convenience. Although it may be practicable to keep a greater number in good condition, more men and greater time are required to close them.

The advantages of subdivision, and the effect of flooding different compartments are not thoroughly understood throughout the service, and it would be of great benefit to establish a "stability school", which would afford a short, but instructive course showing by means of suitable models the alterations in stability and in trim occurring in different vessels from flooding compartments singly and in communication through open doors or injured bulkheads. Information presented in this manner would be of greater practicable value than in the shape of technical formulæ and curves.

The weight of opinion now seems in favor of an even greater subdivision in the vicinity of the water-line, with fewer bulkheads elsewhere, to reduce the liability of capsizing at the expense of some floating power; the usefulness of a ship, when floating keel up,

being questionable. It may be said that bulkheads above the water-line will quickly be rendered useless by the enemy's rapid-fire guns, and therefore, by my own reasoning, there is no use in further complicating the ship; but this is a case when the gain from complication is greater than the loss, as a delay of even five minutes in sinking, may save the lives of the greater part of the crew. Subdivision is the best expedient for reducing the chances of serious accident.

In protective decks there has been a lamentable departure from simplicity; in securing efficiency of minor details, the efficiency of the ship as a whole has been lessened as the decks are pierced in every direction by pipes of all sizes. Some of these, it is true, are provided with automatic valves of uncertain action, but the greater number are only closed by valves located below this deck. When it is struck by a projectile in their vicinity the consequence is obvious, and there is a great probability of stray shots from rapid-fire guns finding some of the many unprotected openings penetrating below the deck and causing fatal damage. The reports of the Yalu fight state that the pumps of all the ships engaged were working furiously, and it seems probable that even on the ships which did not sink, there was much alarm from these causes.

There is no use in weighting down the ship with such an encumbrance unless it be made efficient; no openings should be permitted except those which can be closed in action at short notice, or which must necessarily be open at all times for the working of the ship, and whose risk is known and accepted. Coaling scuttles and ammunition hatches can be closed by water-tight shutters, but all other openings should be concentrated near the machinery space and protected as far as practicable. This can be done by a simplification of piping, by placing dynamo and pump rooms amidships as described later, and by separating the ventilation of living quarters entirely from that of ammunition and store rooms, the inlets and outlets of air for the latter being at the extremities of the machinery space.

Rapidity in coaling ship and in supplying coal to the fire rooms is of vital importance, and continually occupies the thoughts of many able officers. It may not be out of place to mention that the difficulties will be lessened by the various simplifications advocated

by the writer on other pages, for they would enable the lower bunkers to be made of greater capacity, even on the smaller cruisers. Such bunkers can be more easily and quickly stowed; the scuttles in the protective deck can be kept closed in action because there will be sufficient coal below for continuous rapid supply; and with equal weights of coal less space will be required on the berth deck. This is but one example among many, which shows that when any portion of the ship is simplified there are many resultant benefits.

The man is the most important part of the ship's mechanism; but how has he been treated? Compare the San Francisco with the Constellation, the Detroit with the Portsmouth: the proportion of officers to crew has certainly not been diminished, yet the comforts of the officers have been increased while those of the men have been lessened. At night, even in port, they are packed in small compartments, heated by fire rooms and dynamo rooms or steam pipes wet from condensation or leaking pipes, and at sea their condition is even worse. To offset these discomforts, there have been supplied lockers of all kinds, bake ovens, steam cookers, refrigerating machines, and many other conveniences, but in the small space assigned him, Jacky cannot find rest day or night. The service of guns, the care of ship and machinery and their many complicated appliances require a constant vigilance which cannot be had unless the men can rest when off duty; tickling their palates with hot rolls and ice water is not sufficient. Every one having experience on the new ships feels the necessity for larger crews in war, the present complements being inadequate to perform the many responsible and onerous duties required to secure anything like continuous efficiency; they can stand the pressure during a few hours of excitement, but the continued strain of watching and waiting for the enemy must be distributed among more men, in order that everything shall be ready when he appears. Simplification is thus needed in two directions: a reduction in the number of appliances requiring constant attention, so that fewer additional men will be required; and an increase of crew space by curtailing as far as practicable the space now occupied for other purposes.

The space assigned to officers' quarters in the earlier cruisers was large in order to carry more officers than were required for

purely military purposes so that the greatest number possible might obtain sea experience under the altered conditions of modern ships; but as ships become more numerous, fewer officers will be assigned to them, and some of the space now occupied by their quarters can be given to the crew. The innumerable returns, accounts, invoices and other papers now deemed necessary, not only absorb much time from officers and men in mere clerical duties at the expense of true efficiency, but require a large proportion of space in their preparation. With the present rage for scientific investigation and reports, one is tempted to believe that, in a few years, the captain of the hold will have a berth deck office and submit a daily report of the chemical analysis of the contents of his water tanks, a weekly report of the amounts consumed for the various purposes of ship economy, and a quarterly report giving the effect on ship and crew of the varying qualities and quantities of water used; all of which would give very valuable scientific information no doubt, but its collection would be entirely out of place on a warship.

Not satisfied with the crowded state of the ship when newly built, no sooner is she in commission than the demands for more fittings, comforts and conveniences become unceasing; another locker, a book case, a desk, a broiler, a deck gear room and the like, are called for and the crew space is lessened continuously: even when additional crew space is obtained by one officer, others promptly ask for additional encumbrances to occupy it. There is no doubt that in time of war both officers and men would demand a general clearing out from stem to stern of everything that was superfluous or merely convenient; but why not simplify now? During visits to navy yards, if all would join in putting obstructions on shore instead of taking more on board, the gain in efficiency would be very great. It is not necessary in peace that the ship should have the Spartan simplicity of war; on the contrary, let us have every comfort that will add to health and cheerfulness, which does not militate against the efficiency of the ship as a weapon; but if common sense does not rule in their selection, we merely crowd the ship with useless gear liable to get out of order.

The Yalu fight has awakened the service to necessity for abolishing wooden bulkheads and elaborate joiner work, to minimize the

danger from fire and flying splinters; but it is worthy of note that Nelson, after his experience at Aboukir, considered fire as the greatest danger of naval warfare.

Although the boiler is the most important piece of mechanism on the warship, there has not been so much progress in adapting it to the conditions of modern warfare as has been the case with other parts of the equipment, until during the last few years. The space occupied by cylindrical boilers is nearly two-thirds of that occupied by the whole propelling mechanism, and their weight is more than one-half the total machinery weight, for their form is least adapted to close stowage and reduction of weight. Tubulous boilers are less liable to derangement from accident or neglect, they occupying less space, for they can be stowed to better advantage; they are lighter, and steam of higher pressure can be raised in much less time; faults can be sooner detected and easier repaired; but it is only fair to state that their opponents claim that many of these advantages are illusory or are gained at the sacrifice of more important qualities. Many objections of the same nature were offered when surface condensers first appeared, but are heard no more. Efficient boilers should be able to steam quickly and safely at full power at any time during a cruise; other considerations are secondary; but all requirements are met by the tubulous boiler, and its general adoption seems certain.

In the advance from simple self-contained engines to the triple or quadruple-expansion engines of to-day there has been a development of increased power with lessened space and weight beyond the most sanguine expectations of even ten years ago. The Boston and Cincinnati are of practically the same size, yet when the former has one engine the latter has two which develop more than twice the power on the same weight. The complexity necessary to accomplish this is no departure from efficiency when the engines are strong, reliable and durable, for they are directly under the observation of officers who possess skill and judgment to operate and preserve them; and any unusual wear or uncertainty, any fault or weakness can be quickly detected because they are continually in sight. Standardizing has been carried out to a large extent, and there has been much simplification; the Wabash valves of early days have disappeared, and the radial

valve gears of geometrical perfection are being displaced by the old familiar and reliable link motion.

In another direction, however, a great departure from simplicity and efficiency has occurred. The auxiliaries necessary for the functioning of the propelling machinery are no longer attached to the main engines. They are now independent and scattered throughout the whole machinery space, where they cannot receive the watchful and responsible supervision necessary for their efficient performance; break-downs occur and it is necessary to fit additional auxiliaries to provide for such emergencies. It has been stated that the speed endurance depends as largely on the propelling auxiliaries, as the fighting power depends upon the secondary battery. A stronger case could easily be made out for them, but it is the number of auxiliaries which is being discussed and not their duties.

There are many auxiliaries outside of those connected with the propelling machinery, and the following table has been prepared from the best information at hand to show their number and uses on various types of ships; the classification explains itself.

Independent Steam Auxiliaries on Various Ships.

Name and Use.	Number.						
	Indiana.	New York.	Minneapolis.	Cincinnati.	Detroit.	Lancaster.	Alliance.
Propelling Service.							
Main air pumps	2	4	3	2	2		
Main circulating pumps	2	4	6	2	2		
Engine water-service pumps	2	2	3	2			
Reversing engines	2	4	3	2	2		
Turning engines	2	2	3	1	1		
Boiler Service.							
Feed pumps	12	10	12	8	6	1	
Forced draught blowers	10	14	16	6	6	2	2
Ship Service.							
Capstan	1	1	1	1	1	1	1
Steering engine	1	1	1	1	1		
Ventilating blowers	6	6	8	4	4	2	
Fire, feed and bilge pumps	2	4	3	2	2	2	3
Fire and bilge pumps	2	2	3	2	2	1	
Evaporator and distiller pumps	6	4	3	3	3	1	1
Auxiliary air and circulating pumps	2	2	2	3	2		
Workshop engine	1	1	1	1	1		
Wrecking pump		2	1				
Military Service.							
Turret turning	6	2					
Hydraulic pumps	2						
Ammunition hoists	4	2	4				
Air compressors	2	1	1	1	1		
Dynamo engines	3	3	3	2	2		
Handy Service.							
Ice machine	1	1	1	1			
Winches	4	6	2	1	1		
Ash hoists	4	6	8	6	6	1	1
Number of independent auxilaries	79	84	84	51	45	11	8
Number of independent water pumps	26	24	25	17	13	5	4
Number of main engines	2	4	3	2	2	1	1
Number of boilers	6	8	10	6	5	4	4
Displacement	10,288	8200	7375	3213	2094	3250	1375
Complement	424	526	456	292	254	338	157

Economy in coal expenditure is of vital importance: in peace from financial reasons, to save money; and in war from military reasons, to save time. Coal is as necessary for speed to secure the weather gage as are the great guns when once the fight is on. Every unnecessary mechanism should therefore be discarded.

It is proposed by some to produce great coal economy by paying more attention to the design of the auxiliaries and make each one as perfect as possible; but this involves more complication and more skillful attention, so that there will be even greater probability of break-downs than is the case now. This solution of the problem is directly opposed to the principles advocated in this paper.

Others again propose to let the auxiliaries alone and devote greater attention to increasing the economy of the main engines, arguing that increased delicacy and complication are practicable with the skilled supervision and attendance they receive: but it is impossible to obtain economy with the main engines at all the various ranges of power required by the warship, and a choice must be made as to when economy is most desirable. In any case, it can only be obtained by increasing both complication and weight beyond what is necessary or desirable. Reliability is of more importance than economy, and the best and most simple plan seems to be to secure greater power with a given weight of coal by using steam of higher pressures, and by reducing the number of auxiliaries.

Some of these auxiliaries are merely handy labor-saving devices, and are not absolutely necessary. Six ash hoist engines are surely not required on a 3000-ton ship; in many cases their work can be performed to advantage by the deck force who are often not sufficiently employed when the ship is under way, when they cannot be spared from other duties; two ash hoists would be sufficient if suitably placed, as by the aid of leading blocks the refuse of each fire-room could be hoisted through its own ash chute; on smaller ships this could be done by the boat winch. The loss from condensation in exposed lines of piping and from wasteful engines would be prevented, and there would be fewer repairs needed.

The ice machine and permanent refrigerators are luxuries which may be permissible on large ships where the space occupied and

the coal expended is but a small proportion of the total available for other purposes. On small ships, however, the additional comfort they provide for a short time are obtained by a sacrifice of space and a waste of coal which detract from real efficiency.

The number of independent auxiliaries will naturally increase with the size of the ship; their relative cost in coal, weight and space will not be so great, and as the complement does not increase in the same ratio as the displacement, the presence of more and larger guns or boats requires something besides manual power for their rapid manipulation. On the other hand, the larger ship requires more care and attention from the crew simply because it is larger; so that there is no reason why unnecessary auxiliaries should be placed on ships for the mere reason that there is space for them. In general, the ruling principle should be to discard every auxiliary whose functions can be performed by manual power without reducing the fighting efficiency, to reduce the number required for emergency or convenience to the lowest possible limit, and to design such as cannot be dispensed with so that they shall be simple, strong and reliable, with one engine performing several duties when practicable.

The great number of pumps supplied the new ships is especially noticeable. Concerning the speed trial of the Minneapolis, it is stated: "The water in the glass gauges was perfectly steady, and only half the feed pumps (at the moderate speed of thirty-one double strokes per minute) were required to keep up the supply." An emergency provision of 100 per cent. above the maximum requirements appears extravagant, to say the least. The numerous feed pumps, fire pumps and bilge pumps are doubtless due to an exaggerated appreciation of the truth that duplication gives safety, while the equally important truth that concentration gives security is overlooked. The ship's armament is dispersed to reduce the chances of its being disabled by a few well aimed or lucky shots, and the large fighting crew is intentionally scattered for the same reason and to have a reserve available to make good inevitable losses. The motive power, on the contrary, should be concentrated because it must be under perfect control to be useful; it must be protected to the greatest practicable extent; and the smallest number of men, consistent with efficiency, should be concentrated at this duty. Some emergency pumps are essential,

but if the main pumps are well designed and reliable, and receive greater care, fewer emergency pumps will be needed. If all the pumps necessary for boiler supply, drainage, fire and flushing service were situated in a pump room located amidships and below the protective deck, they would receive better supervision and care with fewer attendants, a smaller number would be necessary, and their concentration would greatly reduce the present maze of piping. Instead of pumps in the fire rooms which require unceasing vigilance to counteract the evil effects of ashes and coal dust, the pump room would provide a continuous supply of feed water, and more attention could be paid to firing; while the removal of the other pumps from the engine rooms would enable the attendants there to devote all of their time to the motive machinery; fire rooms and engine rooms would be less crowded and the lower bunkers could be made larger.

The numerous steam auxiliaries all over the ship necessitate many steam pipes passing through berthing spaces and store rooms where heat and leaky joints are very objectionable. Aside from this, the terrible possibilities of even a small pipe bursting from the casualties of action are a sufficient justification for abolishing steam auxiliaries outside the machine space, where possible, even if they be replaced by others more wasteful of coal, provided the ship's efficiency, as a weapon, be increased. The hydraulic pipe and the electric wire can be led to the various necessary auxiliaries with greater ease, they occupy less space, cause less discomfort by their presence, and above all, will cause no serious disaster if ruptured. The steam engine, especially when used intermittently, requires some skill to start it; whereas the hydraulic or electric motor can be used with safety and precision at any time, after the most elementary training, as is shown by the character of the operators of the familiar elevator or trolley car. Although such motors require a high degree of skill and intelligence for their repair, a fewer number of specialists is required, and the great amount of standardizing permits casualties to be quickly repaired at short notice; they also have the advantage of being easier kept in good condition as there is less difficulty from corrosion. Their use for capstans and steering engines, however, is clearly undesirable at present; fortunately, steam pipes for these auxiliaries can be arranged to obviate many of the objections mentioned.

The use of some motive power other than steam necessitates the use of additional appliances for their creation, and any conversion of power involves some waste of coal. It may therefore be thought that the plea for such motors is contradicted by the reasons given in advocating simplicity and economy. This is true; but such motors are advantageous from a larger view of real efficiency, and the departure from simplicity and economy is not so great as might appear at first sight.

It is not wasteful of coal when a new weapon like the torpedo, a new safeguard like the electric light, or a marked increase in health and comfort are the result. Power is transmitted to such motors with but little loss even through flooded compartments; but there is a great loss from condensation in long lines of steam pipes, and steam power cannot be transmitted at all through flooded compartments.

A discussion of the relative merits of electric, pneumatic, and hydraulic motors is out of place; it is sufficient to say that the development of applied electricity on the warship is rapidly increasing, now that its possibilities and limitations are better understood, and its advantages for military purposes are appreciated. Its use for search lights and signals, ammunition hoists, gun mounts, turret turning, range finders, firing circuits and the like is well established, while for lighting and ventilation it is invaluable.

Successful electric counters, telegraphs and indicators are the ideal appliances for these purposes. There should be many places about the ship where the captain can direct the ship, and although the present mechanical appliances are generally reliable, they are cumbersome, and it is impracticable to scatter them owing to the practicable difficulties in getting proper leads. The electrical appliances thus far provided, are unreliable, but with their development will come efficiency.

Voice pipes are cumbersome, are a source of danger, and are unreliable, because confusion may arise from orders imperfectly understood, as the central station is better in theory than in practice. What a gain there will be when a suitable telephone shall be developed which will enable the conning tower to distinctly transmit orders to all parts of a ship!

In electricity, as in everything else, we shall stray from efficiency unless simplicity and economy be borne in mind. Such toys

as automatic electrical whistles, automatic steering compasses and similar fittings are unnecessary and should be discarded. The electric light is so convenient that the temptation is very great to lose sight of economy in the installation and use of lamps. Fixed lights are located in storerooms and other places where portables could be used; and officers are very apt to use the electric lights on trivial occasions where hand lanterns would answer, or to consider the lamps in their own quarters as a necessity instead of a luxury;—how many stop to think that it takes 2 pounds of coal per hour for a sixteen-candle-power lamp?

To complete the concentration of the principal auxiliaries within the machinery space, the dynamo room should also be located amidships and below the protective deck in a separate compartment; a better and more economical system of wiring would be possible, an easier and safer generation of electricity due to better ventilation and dryer steam; the dynamos would be better protected, and the crew would be saved much annoyance and discomfort.

The maze of piping on the warship of to-day is fully appreciated only after experience on bilge boards. Pipes are found everywhere, encumbering the double bottom, hiding the inner bottom, and obstructing coal bunkers, berthing spaces and officers' quarters. It is no exaggeration to say that their total length exceeds that of the standing and running rigging of sailing ships of equal size, and that the number of valves is greater than the number of blocks. It is claimed that the presence of all these pipes and valves is as necessary to the warship of to-day as the rigging and blocks on the ships of 1812, and that there will be a loss of efficiency if they are reduced in number and simplified. This parallel is not a happy one, for the rigging was reduced in amount and was simplified whenever necessary by furling sail or by sending down yards and spars; the pipes, on the contrary, must always remain as fitted. The rigging was always *en evidence* its weakness could be detected before injury was done, and its defective parts could be quickly repaired or replaced by the crew, with the stores and appliances on board; but the piping is generally hidden from view by floor plates, stores and lagging, and its interior is never seen; its weakness develops gradually and can rarely be detected until a break-down occurs, which, usually, can only

be temporarily repaired by the crew, as it is impossible for them to replace any except the smallest-sized pipes.

Again, the location and use of every part of the rigging were so familiar to every man on board, that on the darkest nights, or in sudden emergencies a mistake was extremely rare; and when a mistake did occur, it quickly betrayed itself and could usually be quickly remedied. What a contrast with the warship of to-day: how many officers and men are there who know the names and uses of every pipe they see, how many men know the leads and combinations necessary to flood this compartment or to pump out that one, if the routine gear is out of order? When it is not uncommon to find that water has entered the double bottom from negligence or ignorance, how great must be the danger in the excitement of action if this can occur in the daily routine of peace? What can be done to simplify? Some suggestion concerning steam and ventilation pipes are offered elsewhere. With drain pipes, there has been a tendency towards requiring that every compartment should be emptied by every pump, but experience with the labyrinth of pipes and fittings already fitted has shown that many of them are rarely utilized. It is desirable, no doubt, to have the drainage complete; but it is more desirable that this should be done in such a simple and reliable way that every petty officer can learn to manipulate the system and thus eliminate the danger arising from entire dependence on specialists to operate the multitude of valves, when blunders may imperil the safety of the ship.

The many small pumps required for the fresh water service are a fruitful source of annoyance, but the growing system of having one pump fill a cistern located in or above the hammock berthing, from which the water is distributed throughout the ship by gravity alone, is exactly in the line of progress advocated. Those who have had experience in breaking out a lower bunker on the eve of sailing to get at a leaky joint, may think that an effort should be made to standardize the leads of pipes; but if joints are located in accessible places, and if the pipes do not pierce the protective deck outside the machinery space, further simplification will not be necessary.

Brassey says: "Nowhere more than in the forces of the navy and the army do we see indications of that thoughtless impatience

to be in the new fashion of the day. Should it not be remembered that an instrument of war depends for its value not only on the weapon itself, but on the training and knowledge of those in whose hands it is placed?" Officers naturally desire to have everything of the latest and best type regardless of the cost, when greater efficiency can be secured. Yet true economy is but another term for efficiency, and when the service realizes the immense improvement which a well developed system of economy will bring about, gratifying results will follow. This does not mean that fighting power should be subordinated to a parsimonious use of stores, or to a niggardly policy of repairs, for that is false economy; it does mean, however, that extravagant and wasteful expenditure is an evidence of incompetence or carelessness.

With our form of government, it is not easy to secure money for any purely military purpose unless its necessity is self-apparent. Although it has been realized that high class ships are needed and that high prices must be paid for them; we cannot expect large annual appropriations for the maintenance and improvement of these ships unless it be self-evident that carelessness and extravagance do not exist, and that the necessity for economy is appreciated. It is imperative that excellence be secured by economy, for if there is carelessness or waste, a disastrous reaction will set in, and the navy will again suffer as it did twenty years ago.

First cost is always important; but when a greater expenditure will secure greater fighting power, or will secure greater economy in peace without lessening the war efficiency, there is no extravagance.

Economy in running expenses is essential. These are of two kinds: military expenses, for ammunition, coal, stores, pay, etc., which are regulated by the exigencies of the service and by the policy of the day; and mechanical expenses, for repairs or improvements, which are more or less regulated by the service itself, for they depend upon the ship's design and workmanship and upon the crew's skill and vigilance. The expense of repairs due to wear and tear and to accidents is one criterion of a ship's efficiency, because their amount can be lessened by vigilance and the proverbial "stitch in time;" and as the money available is limited in amount, the less there is required for these expenses the greater

the amount available for improvements. Officers whose intelligence and fertility of resource secure economy in peace by maintaining efficiency with the means at hand, will not only add to their reputations but will be developing those qualities which will prove most valuable in war.

Jurien de la Gravière, in speaking of Nelson's long watch off Toulon for the French fleet, says: "Chose digne de remarque! le bouillant amiral managait ses vergues et ses voiles dans les circonstances ordinaires plus soigneusement que son escadre ou son vaisseau dans les occasions décisives." The necessity for constant supervision and attention to detail is more important on the complicated warship of 1895 than on its predecessor of ninety years ago; greater and increasing responsibilities therefore rest on the personnel of to-day as compared with that of the past. Competition is keener and increasing; each new ship is somewhat better than the one before it, and it rests largely with the most intelligent use of the matériel to gain the advantage. No matter how simple and perfect the mechanism, the mere fact that it is a mechanism requires skill and vigilance for its care and management.

Seamanship is the art of providing, preserving and handling ships and their equipment; and the knowledge of this art is more difficult to acquire than ever before because of the many different types of ships, which have their special purposes and peculiarities. With the general principles of this art all officers are familiar, and it is merely a question of time to successfully adapt them to the peculiarities of individual ships; but this time must be taken from other duties, officers are so overwhelmed by a mass of petty details, that a considerable period must elapse before they can grasp the peculiarities of her equipment and summarize her qualities so as to be prepared for the contingencies of service afloat.

This period could be greatly shortened by a study of a "ship's manual" which would contain the results of the investigations of all those connected with her building and equipment, and the results of the experience of those previously serving on her. Such a manual should state, briefly but clearly, the ship's merits and demerits, laying stress on those duties which she is best and least qualified to perform; with descriptions of the armament, ammunition and armor; of the machinery, with statements of the speed, horse-power, and coal endurance under various conditions; of the

electric plant, with explanations of peculiar appliances; of the hull and its subdivisions; of the drainage system, and the method of pumping or flooding various compartments and a statement of the ship's trim and behavior when the large compartments are filled. It would also describe the handiness and qualities during all weathers, and mention the parts of her equipment which are most liable to give trouble. In other words, the ship's manual would contain in a concise form that information which every officer gathers and assimilates as best he may, and it would be of the greatest value in rapid mobilization of ships in the reserve.

The drudgery of bilge board duty becomes very wearisome, but in no other way can the ship be known so well and thoroughly. When an officer is able to mentally photograph the interior of every compartment with every important fitting in it, he is far better equipped for handling the ship, and for quickly deciding what should be done in an emergency, than one who has perhaps spent even more time in pouring over plans, curves and tabulated data.

Accuracy and dispatch are the fundamentals of successful seamanship, and they are best obtained by practical observation of every appliance and fitting in the ship. When all things remained stationery, as in the times of sailing ships, the art of seamanship was largely formulated, and for every probable contingency the best line of action had been established by precedent. But to-day there is little or no precedent and nothing is formulated, for everything is changing.

The contingencies themselves are often unlooked for and the best procedure for one ship may be worst for the other. Unremitting vigilance and complete familiarity with every detail on the part of the officers are more necessary than ever before, because the men have not yet learned the requirements of the new seamanship, and much of their work must be done for them. This knowledge of detail is valuable in another way for it gives an insight into the causes of failure, and an appreciation of the uselessness of refinements that are seldom or never used. Without this knowledge proper suggestions for simplification and improvement cannot be made.

Roosevelt says: "The captains and lieutenants of 1812 had been taught their duties in a very practical school." It was to

this knowledge of their duties that the perfection of our warships of that period was largely due, for they were able to suggest improvements of practical value to builders who had long been accustomed to constructing and equipping ships which could fight as well as they could run. To-day the value of proposed improvements is largely a matter of judgment based upon the behavior of the ship in peaceful cruises or manœuvres. How important, therefore, it is that no ideas or suggestions should be lost, particularly those which arise after some annoying or perplexing experience has shown the best way of overcoming some unforeseen difficulty. There have been numberless suggestions for improvement during wardroom discussions, but they have usually been forgotten.

It is thought that a "suggestion book," in which every officer would be encouraged to record the results of his individual experiences and his suggestions for improvement, would prove of interest and utility. If it were possible to adopt the German regimental system, and have occasional discussions by all officers of the various questions arising, and record the ruling opinions in the suggestion book it would be of still more value.

Such a book would have a twofold usefulness: for those afloat, it would accentuate the familiar fact that a ship is a compromise; that what is added to one quality must be taken from another, and by showing the cost of improvements, it would increase the desire for economy in order that the improvements could be carried out. For those ashore, it would show where improvement was most desirable, and it would recall the onerous conditions of sea service, which are so quickly forgotten after a few months of shore duty.

In suggesting and making improvements, however, let us avoid jumping at the conclusion that every new device makes obsolete everything preceding it; for it is the demand for perpetual change in minor details which fritters away money that could be more efficiently used on more vital alterations. The better way is to spend money only on those alterations that are absolutely necessary, until such time as the ship is laid up for a general overhauling and refitting. At that time, especially if the suggestion book has been utilized with the proper spirit, the money which has been saved on useless or unnecessary alterations can be expended to

produce a harmonious whole or at least a complete development of one or more qualities, instead of having a patchwork of incomplete improvements which give satisfaction to no one. The knowledge that there is not sufficient money available for more improvements should increase the desire for frugality, as economy is a revenue in itself.

If simplicity and economy be carried out, as suggested in this paper, a more efficient ship can be built for the same money in the first place; there will be less expense in making good wear and tear; and the ship can be kept in line with the onward march of naval science.

The ideal seaman for the modern warship is admirably described by Luce: "The highest expression of the trained man is to be found in the able seaman and expert gunner combined." The necessary complication of hull and equipment requires from the men a reasonable amount of mechanical skill and capacity for their effective use and care. Much has been said and written concerning methods of training seamen and making them comfortable, and the writer merely wishes to call attention to some particular qualities which are touched on in this paper.

It is not possible for one man to have a thorough knowledge of the entire ship, and some specialists are therefore necessary, although there is little room for the man who knows one thing only. The most valuable men are those who know their own duties well, and who have a general knowledge of the duties of others, for they do their own work more efficiently, and do some portion of the work of others in an emergency. This is well recognized in the training of both officers and men; but greater efficiency can be obtained when we have a larger number of men who are mechanic-sailors; above everything else they must have the bold, self-reliant spirit of the old seamen. We want men who know what to do and how to do it, who are quick to see the necessity for action, and who are prompt to act without waiting for orders; such men cannot be mere sailors, for they lack the necessary mechanical skill; nor mere mechanics, for they lack the necessary knowledge of the sea, and their point of view is apt to be too narrow.

We have such men but we need more, and all should be taught a wider range of duties. The boys who can take apart and replace

the breech mechanism of a rapid-fire gun can quickly learn to overhaul the gear for operating a water-tight door; and the men who know how to use and care for the torpedo plant can easily learn to care for the steering gear. The knowledge of drill and monkey-wrench is as important as that of marling-spike and mallet; and the skill to pack a stuffing-box or hand-pump, or to fit a rubber gasket is as necessary as the skill to reeve off a fish tackle, or a boat's falls, or to heave the lead. To get and keep the right man is not easy; he must get good pay and good treatment, but with them he must accept the altered conditions of the service, must feel his increased responsibility and must expect prompt punishment for every act of carelessness or negligence.

The lack of an American seafaring element to draw upon in war is a deplorable fact, but there is consolation in the thought that many valuable men can be had in war from another class. The new navy is popular throughout the country; and when the emergency arises it will require but small encouragement to obtain thousands of volunteers from the young, alert and self-reliant American artisans, who now find an abundance of well paid work on shore. Such men under capable petty officers, would quickly adapt themselves to sea life and the special mechanical appliances found on board the modern warship. After a few months' training they would be more valuable in the gun and powder divisions than the best north countrymen, who are sailors from instinct, but who do not have that adaptive and ingenious faculty which is peculiarly American. Seamen are more needed than ever before, for their special knowledge is absolutely essential. The experience of the Romans in the Punic wars, of the Spaniards with Armada, and of the French in the time of Napoleon, is sufficient to show that knowledge of wind and weather cannot be obtained by a royal decree or a general order; and that without this knowledge the proudest fleets are useless. But it is also true that only a small number of men who are seamen and nothing else is needed on our ships to-day where sails are conspicuous by their absence. There are certain duties which none but the seamen can perform; and even if this were not so, his presence is necessary for the fostering of those peculiar qualities which are needed by those who "go down to the sea in ships," even though it be on a floating battery which never sees blue water. The necessity for men

who are more than mere seamen is recognized in the training given to the seamen gunners, and in the appointment of boatswains and gunners who have had this admirable training. With more such men, and with carpenters who have been navy yard apprentices, our ships will be more efficient and better cared for, and executive officers can devote less time to petty details, and occupy themselves in more important and congenial administrative duties, and economy will be more practicable.

To attain this desirable end with the crews of to-day, they must be made to realize that no duty is unimportant, that every man on the ship is there to perform as many duties as possible, and that carelessness is the worst of faults. They should feel that it is as discreditable to be ignorant of the leads and uses of pipes and electric wires now as it was to be ignorant of the leads and uses of the rigging. Petty officers in particular should know the use and care of every appliance and fitting in their part of the ship, and should be taught to foresee and meet the many emergencies which may arise. In the minute subdivision of the present warship, the petty officers must often be relied upon to remedy defects at once, instead of waiting for orders. In the action between the Constellation and l'Insurgente, Porter in the foretop, finding that his hails to the deck were disregarded when the foretopmast was badly wounded near the lower cap, cut the stoppers and lowered the yard, and thus insured the victory. Such appreciation of danger, and such prompt action to meet it, is a lesson to officers and men alike, for if Porter and his men had not been taught the use and necessity of this manœuvre it could not have been accomplished.

The superb condition of the ships coming from the Pacific for the Naval Rendezvous shows what may be done by proper training on long cruises. On the home station, however, one often sees a spirit of carelessness and recklessness that is opposed to efficiency and economy. To some extent, this may be due to the present unfortunate necessity for transferring men from ship to ship; the men have not time to learn their ship, and they feel little interest or responsibility in her.

But it is mainly due to the feeling that a navy yard is near by, and that the defects due to their own carelessness will there be made good by some one else, instead of by themselves. This can

best be remedied by impressing every one that the appliances at hand must be utilized, and that the numerous small defects which are sure to occur must be made good on the ship whenever possible.

Many times victories have been won by sailing ships, merely from rapidity in repairing damages. After close cannonading without decisive results, although each ship had suffered severely from her opponent's fire, it was common for them to separate and attempt to repair damages; the one which was first able to haul into position to rake the other was certain of victory. It may be said that this is no longer true with the modern warship, as damages can only be made good at navy yards. This is only partially true, for there will be many minor injuries which can be repaired at sea, and with two ships similarly damaged, the one with a crew which is able to make even temporary repairs will be most efficient because she will be more formidable *en route* to a navy yard, and will be ready for active service sooner than the other. This is well illustrated by the behavior of the Japanese ships after the Yalu fight; and in our own Civil War, great delay and embarrassment were experienced from inefficiency and incompetence.

To keep the mechanic-sailor after he has been trained to his new duties, more pay must be offered him, or he will seek the higher wages to be found on shore. Yet true economy and efficiency will follow when this is done, for ships can be kept in a more perfect state of readiness, and the additional expense for pay will be much less than the expense of increased repairs due to ignorance or incompetence. It should be thoroughly understood, however, that any increase of pay must be accompanied by a strict accountability, and that any negligence will be followed by severe punishment.

Colomb says: "When man power is capable of doing the work, I cannot help thinking it is very much better, on board warships, that the man power should do it." This is exactly in accordance with the simplicity and economy advocated in this paper. Such fittings as the automatic whistle and the automatic steering compass are complicated and delicate, and their cost for installation and repairs is out of all proportion to their practical usefulness. The warship carries a sufficient complement to afford men to do the work of such devices, who thereby learn those habits of alertness and self-reliance which are so valuable. In manning boat falls,

ash whip and fish tackle, coal is saved, and the crew exercised. A voice tube and annunciator to a military top may function reliably, but it is simpler and surer to hail the top from deck. It is better to abolish all small fittings which are not necessary and which are so unreliable that they may fail just when the men are accustomed to their use and depend upon them in emergencies. Larger appliances must be supplied for use when there are few men available, but their use should be restricted to such times, except when dispatch is required.

Soley's comparison of the actions between the Shannon and the Chesapeake, and between the Weehawken and the Atlanta might have been used as the text for this paper. He says: "In both cases the victorious captain . . . is bold and prudent, attentive to details, minutely careful in preparation"; the victorious ships were "always ready for any kind of service"; with the losers "there was the same absence of preparation." Ships and crews were as nearly perfect as the naval science of the day could make them, and that is what is wanted with the warship of to-day.

Perfection in the ship is not to be had by crowding her with complicated and fragile mechanisms or superfluous fittings upon which no reliance would be placed in war, and which are seldom, if ever, used in peace, even though the ship be fresh from a navy yard. True progress lies in supplying those appliances which are useful and reliable, and in subordinating their individual efficiency to that of the whole ship.

Perfection in the crew is to be had by encouraging versatility and by restoring the old spirit of self-reliance, so that the complicated fittings which are necessary on modern warships can be maintained in constant readiness for use.

Improvements are continually necessary; but they cannot be had unless economy provides the money, and they will rarely be of permanent value if they are the expression of hastily conceived notions, or cause a departure from simplicity.

Simplicity and economy cannot be secured by the efforts of the few; the concentrated desire of the many as manifested in their daily duties, can alone cause a lasting improvement. Complication has arisen from the demands of the entire service, and the remedy is in its hands, for it is only by the cordial cooperation of every one that the warship can be made an efficient weapon.

DISCUSSION.

Commander C. F. GOODRICH, U. S. N.:—A more timely article could not have been penned, nor one more urgently needed, to call attention, in tones not to be misunderstood, to a tendency of our service which is full of evil. Every officer who has served on board of a modern ship must have felt the inconvenience arising from break downs of delicate machinery and apparatus, upon which reliance had been placed until the habit of trusting to them had become fixed. Convenient and useful these machines and appliances are, but the question seems never to have been asked, Do they sufficiently increase the ships' fighting efficiency to justify their adoption? or, What provision has been made for doing their work in the event of failure during an action?

There are three systems which especially offend against the doctrine of simplicity—the electric call and alarm circuits, the drainage, and the auxiliaries.

It would seem as if officers had so clamored for easy communications that they had been granted electrical calls from each to every point on board, so numerous and so intricate are the leads in some instances. I should be afraid to say how large a percentage of these circuits I believe to be usually out of order. As to automatic alarms—their annunciators are as ornamental as they are doubtless costly—but, too often, the vital organs in the bilge and bunkers are out of order. Why *should* they replace that human vigilance which is the essential condition of safety? Would a captain be cleared of the charge of negligence if he lost his ship through failure of an electric alarm?

The writer has dwelt upon the drainage maze of pipes even less censuringly than he might. After what he has said it will be impossible in the future to repeat the errors of the past.

The auxiliaries should either be operated without steam, or they should be abolished rather than lead steam pipes through living spaces—I had almost written outside the engine and boiler compartments. Personally, I see no reason why all really vital to the ship's proper functions, should not be electrically driven. The electric motor is now in daily use on tram cars and under conditions which make shipboard employment a laboratory experiment in comparison.

The ventilation of our ships as at present designed is fraught with danger in the event of the sticking of the automatic valve and the consequent free passage of water from one water-tight compartment to another. I was told by Mr. Cramp that the air ducts for the New York covered one of his docks and stopped much yard work until gotten out of the way, and in their place on board where they took up the room of 300 tons of coal. I am not original in suggesting independent electrical ventilating fans at such points, *and such only*, where they are indispensable, discharging directly upwards through tubes that pierce no bulkhead. While this

suggestion appears to involve a departure from simplicity, I think, upon study, it will be found to be within the author's limitations.

The proposed "manual" needs no endorsement, its value is axiomatic. The "suggestion book" is equally admirable. Personally, I have adopted its leading features by requiring my subordinates on board ship to submit to me written memoranda of their recommendations and criticism upon the hull and fittings for embodiment, at my discretion, in my periodical reports to the Bureau of Construction. I am loath to urge upon a service already deeply laden with papers and returns any additional burden of a clerical nature, but the manual and suggestion book seem sufficiently useful to meet even this objection.

It is not often that an article can command such hearty agreement as I am sure will meet this sermon on Simplicity. It is a contribution to the literature of the profession as notable for its subject as for the manner and style of its treatment.

I hope the author will pardon me if I rewrite one of his clauses and conclude by saying, "nothing should be added unless the advantages of its presence more than counterbalance the *advantages* of its absence."

Lieutenant H. S. KNAPP, U. S. N.:—The service is fortunate in having presented to it in such an able way the important subject of Mr. Baxter's essay, and I believe that his general conclusions will meet with hearty approval. To my mind, he strikes the key-note in his remark, "The man is the most important part of the ship's mechanism," and what he has said in that connection appeals especially to me as a sea-going officer. In the desire to surpass like ships in foreign navies, many of our own ships have been so filled up with weapons and machinery as to fatally crowd and discomfort the men. Heavy batteries, torpedoes and powerful machinery are all desirable, no doubt; but every addition in either direction involves additions to the complement, while, at the same time, there is less room for the greater number of men and for the increased supplies of all sorts required. The question is one of compromise, but the compromise should not ignore Jack; in too many of our new ships it does.

I am serving on board one of our smaller ships that admirably points the moral. On a displacement of about 2000 tons only she carries a main battery of nine 5-in. B. L. Rs. (it is proposed to add another), four automobile torpedoes of two distinct types, and the engines and auxiliaries develop 5400 I. H. P., giving a trial speed of a trifle over 19 knots. As a consequence, the cubical air space per man is much less than that required by statute for emigrants on ocean steamers. Considering the necessary heat from the boilers and dynamo-room, which latter is immediately below one compartment of the berth deck, it will be seen how crowded and uncomfortable the men are at night. Nor are they much better off by day, except in fine weather, for the forecastle is their only comfortable place when it is hot, and when it rains they cannot stay there. Bad as this is,

considerably less berthing space was allowed in the original design, which provided for a somewhat heavier armament. I leave out of consideration the Gehenna-like side passages which were provided with hammock-hooks by some genius.

Lest I be accused of growling without suggesting a remedy, I will state briefly in what way changes might be made that would, in my opinion, result in a better ship. In the first place, I would leave out altogether the automobile torpedoes, of whose value, on small ships of the cruiser class, I am skeptical. But the great change that seems to me desirable is in the boiler power. Three-quarters of the power now installed, 4000 horses say, could be distributed in two double-ended and two single-ended boilers, and would give the ship a speed of 17 knots. This would result in the saving of space below and on the berth deck equal to the length of a single ended boiler plus the width of one fire-room. Below the berth deck a large additional coal space could be provided, together with increased hold and store-room space in which the ship is lamentably deficient. On the berth deck there would be an additional compartment available for berthing and messing space. The result would be a great increase in habitability, considerable gain in stowage room, increased coal capacity, increased radius at full speed of at least 700 miles, largely increased radius at cruising speed,* and a diminished number of auxiliaries, together with a smaller number of men. To offset these advantages there would be a sacrifice of two knots at extreme speed, though a 2000-ton ship is no laggard that can make 17 knots.

The changes proposed are all in the direction of simplicity. To my mind, however, the greatest gain of all would be in habitability, which must have an effect, and that so great as hardly to admit of exaggeration, on the efficiency of the ship as a war machine, especially if the proposed changes cross the line between comfort and discomfort. I am convinced that changes such as I have indicated would increase the efficiency and value of the ship for both peace and war.

My criticisms have been made on the one ship with which I am most familiar; but conversations with many brother officers convince me that, in a general way, they are true of almost all of our new ships of less than 5000 tons. I will trespass no further on the pages of the Proceedings, beyond expressing my belief that the sentiment of the service at large is entirely in accord with the spirit of Mr. Baxter's paper.

Lieutenant WM. F. FULLAM, U. S. N.:—Practical naval officers who go to sea in ships of war, who have opportunities to note the workings and defects of the many mechanical devices now supplied, and who have

*From observed performances, the cruising radius at full speed, 19 knots, is about 1450 miles in 3¼ days; at 11 knots, 30 tons per day, 2800 miles in 10⅔ days. By the proposed changes these radii become: at full speed, 17 knots, 2225 miles in 5¼ days; and at 11 knots, 30 tons per day, 3600 miles in 13⅔ days. It is estimated that 90 tons of coal more than the present capacity can be carried, with an allowance of about 1200 cubic feet for stowage in addition.

stopped to consider how these ingenious and labor-saving machines would probably fail and cause confusion in battle, will heartily welcome Mr. Baxter's article on "Simplicity." A few months' experience afloat should be enough to convince any man whose duty it is to study how to make ships efficient for the one emergency for which they exist, that we have passed beyond the limit fixed by practical considerations, in the introduction of complicated mechanical contrivances on board ship. It is fortunate indeed that Mr. Baxter has brought the subject up, and it will be equally unfortunate if the discussion does not bear good fruit.

It has too often been asserted that those who *use* weapons are not supposed to know much about the mechanism, and that they should not presume to criticize the design. This is an absurd theory, of course. The inventor should always be glad to utilize the experience, and to benefit by the advice, of the man who uses the arm. It is gratifying to note that Mr. Baxter recognizes this fact. The idea of a "suggestion book" on board every ship is an excellent one. It could be kept confidential, and only referred to by those who properly have occasion to deal with such questions.

Mr. Baxter covers the ground so thoroughly that there appears to be little chance for additional suggestions. I can take exception to no statement or argument in Mr. Baxter's paper, except in the one particular that the ice machine is an unnecessary "luxury." Even this statement may be perfectly sound as regards the majority of ships. But in the case of the Raleigh, the capacity of the fresh water tanks is so limited, and their situation is such, that the ice machine is a practical necessity for cooling the water for the men to drink.

In the limits assigned for a printed discussion, it is hardly possible to dwell upon the many important points of this valuable paper. But there is one idea that demands special attention. Mr. Baxter has recognized that, after all, the *man* is the most important machine on board a fighting ship; that he must be kept in good condition; that he must not be crowded out by other machines; that he must be given space in which to live like a human being. "Every one having experience on the new ships feels the necessity for larger crews in war, the present complements being inadequate to perform the many responsible and onerous duties required to secure anything like continuous efficiency; they can stand the pressure during a few hours of excitement, but the continued strain of watching and waiting for the enemy must be distributed among more men in order that everything shall be ready when he appears." This statement is sound. And to the "strain of watching and waiting for the enemy," we must add the strain of coaling and cleaning ship. There are not enough men to bear the burden and drudgery of routine work afloat.

The essayist displays sound judgment regarding the *kind* of men needed in the modern ship as well as the number. A Pinafore theory that the day of the sailor is passed is being urged by certain individuals who see "as

through a glass-eye darkly." Because *sails* are abolished they think the sailor has no place on board a modern ship! His usefulness, they think, is measured by the first syllable of his name—"sail." But this argument is not deep. It cuts both ways—this play upon syllables. It has been well said that "the sailor is also a *sea*man, and the *sea* has not yet been *abolished*." As long as there is water enough to float the navy, we shall need seamen. The necessity for seamen is daily felt by officers on board mastless ships. Their training should be somewhat different, as Mr. Baxter says, but not so different as many people imagine who have nothing but imagination as a basis for their opinions. There is hardly a quality of the old-time sailor that is not needed in the man-of-war's man of to-day. Something should be added, but little taken away, to convert the man of the past into the man of to-day. The change can be made with great ease. With the seaman, we simply have to add *one* quality to the *ten* he already possesses. With any other man, we should have to add *ten* qualities to the *one* he already possesses. Let us take the simplest solution and stick to the best man.

When naval architects recognize the vital importance of the human "machine"; when they provide for the stowage of *men* as well as for the stowage of *material*, we may hope that line officers will give more attention to the subject. To bring the man to the highest possible state of efficiency; to attend to the "care and preservation" of *this* piece of mechanism, is peculiarly their function—it is their first and most important duty. And they should not approach the subject with timidity, but with the fearlessness and practical sense that should distinguish those who may command ships and squadrons in battle. Questions regarding the *number* of men, the *kind* of men, and the *development* of men have not received their proper share of attention. Officers are court-martialed for permitting iron to rust, and machinery to deteriorate. They are encouraged or forced to devote too much time and thought to naval material. They hesitate, for various reasons, to deal courageously and thoroughly with the one question that most vitally affects the fighting efficiency of the navy—the question of *men*.

Lieutenant JOHN M. ELLICOTT, U. S. N.:—In his "Suggestions for Increasing the Efficiency of our New Ships," Naval Constructor Baxter has given to the service a most fortunate and opportune paper.

In reconstructing our navy we have built ships of every type, and with many variations in each type, so that, with our first battleships now completed, we have just reached the point where we can compare the results and eliminate, simplify and standardize for future construction. Agreeing then as I do with nearly every suggestion in the paper toward simplicity in the fittings of our men-of-war, I cannot help feeling regret and disappointment that the author avoids the very groundwork of simplicity, the standardizing of designs.

Mr. Baxter states truly that "standardizing is the most obvious means of securing simplicity," and that "standardizing reached its highest perfection at the opening of the century, when *ships of the same type were practically alike from keel to truck*," but almost immediately afterward, he abandons these important premises by saying, "the question of design is too large for consideration."

On the contrary, it seems to me that unless we begin with the question of design, the question of simplicity in fittings becomes almost too large for consideration. I believe that in the Indiana, New York, Columbia and the Newport News gunboats we have reached best adapted types, and that their designs could be adopted as standards in their respective classes to such an extent that variations from them would not materially affect the standardizing of mechanism and of its distribution and fittings in them as adopted standards of design.

It therefore seems to me that we could succeed in standardizing and simplifying our men-of-war and their fitting, in the following manner: let the Board of Bureau Chiefs advise the Secretary of the Navy which of our new men-of-war most nearly represent standards in each class and type. Let the Secretary then assign a naval constructor to each ship so designated, to cruise on her during some period of manœuver which will fully test her efficiency for the purpose for which she was built, as a member of a "Standardizing Board," composed, beside himself, of the captain of the ship, the executive officer and the chief engineer; this board to decide upon standard types of auxiliaries, standardized localities for same, standardized leads for all conduits, and to advise upon equipments which can be discarded; having always in mind the efficiency of the ship as a fighting machine. Let the plans of these boards, after being passed upon by the Board of Bureau Chiefs, be adopted as standardized plans for interior fittings, and in future construction let these plans be followed as nearly as the ships' designs will permit, until in some parts there is discovered room for obvious improvement. It strikes me that such a method of procedure would be more directly to the point, and have a more exact end in view than the keeping of "suggestion books."

I should like to ask the writer why he regards hydraulic or electric motors, "clearly undesirable at present," for capstan and steering engines.

I shall be sorry to see voice pipes condemned as "cumbersome," "dangerous" and unreliable," until that "suitable telephone" suggested by the writer shall have been developed. I cannot see that voice pipes are particularly cumbersome or dangerous, and they are chiefly unreliable, because poorly installed. They are fitted too much like water spouting, with sharp angles at every change of direction, these changes, too, being often unnecessarily numerous. Easy curves at such points and a minimum of turns would render the pipes absolutely reliable for the transmission of orders until cut by shell. Duplication of pipes to vital points with different leads would reduce the chances of that misfortune. I do not believe in a

central station for voice pipes, but in separate pipes connecting all important stations between which the voice alone would not carry, manual signaling would be impracticable, or messenger service too slow in battle. Such pipes, by following as far as practicable other conduit leads, would not detract from simplicity. Many voice pipes now installed are redundant, while more important connections are lacking.

As for telephones, they will function afloat *in peace* as well as they do on shore, but what officer at all familiar with the not infrequent vexations of intercourse over the ordinary commercial telephones would place any reliance in the best installment of such instruments on a battleship amid the din of combat? Let us give more thought, then, to voice pipes, for the time may come when one properly installed will win a battle.

It will be noted that it is chiefly for what he has left unsaid that I criticise Mr. Baxter. What he has said, with the exceptions noted, strikes me as so opportune, so important and so correctly suggestive, that I should like to see a paper by him on standardizing designs, even though he now regards the subject as too large for consideration.

Naval Constructor W. J. BAXTER, U. S. N.:—This favorable discussion encourages the writer to hope that the service at large will be more willing in the future to do its part to secure the benefits arising from "Simplicity."

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

Οἱ μὲν θεοὶ πάντα ἀνθρώποις πωλοῦσιν, ὁ δὲ μισθὸς ἔργον.

THE BATTLE OF THE YALU.

By Ensign Frank Marble, U. S. Navy.

The following account of the battle fought between the Chinese and Japanese fleets off the mouth of the Yalu river on September 17, 1894, is based upon the reports printed in the *Army and Navy Gazette*, London, Sept. 22 to Dec. 1; the *Engineer*, London, Oct. 5; *le Yacht*, Paris, Sept. 29, Oct. 6, and Dec. 1; the *Japan Daily Mail*, Yokohama, Oct. 11; the *New York Herald*, Nov. 7; the *New York Times*, Dec. 9; and several letters in the *London Times* and other papers. The clearest accounts of the manœuvres of the two fleets are found in the Japanese official reports, printed in the *Japan Mail* of Oct. 11 and *le Yacht* of Oct. 6.

About the 12th of September the Chinese fleet under Admiral Ting was assembled in Port Arthur, under orders to convoy a fleet of six or seven transports from Talien Wan—25 miles northeast of Port Arthur—to Wiju, at the mouth of the Yalu river. The first reports were that this fleet sailed on the 14th, the later ones that it started in haste upon receipt of news of the victory of the Japanese army and the capture of the citadel of Ping Yang, which occurred early in the morning of the 15th. However this may be, the Chinese fleet with the transports in convoy arrived in the Yalu, which is about 200 miles from Port Arthur, on the afternoon of the 16th; and the transports proceeded up the river to disembark their troops.*

The Japanese fleet, in the meantime, had been in the Ping Yang inlet acting in concert with the army, and after the victory there

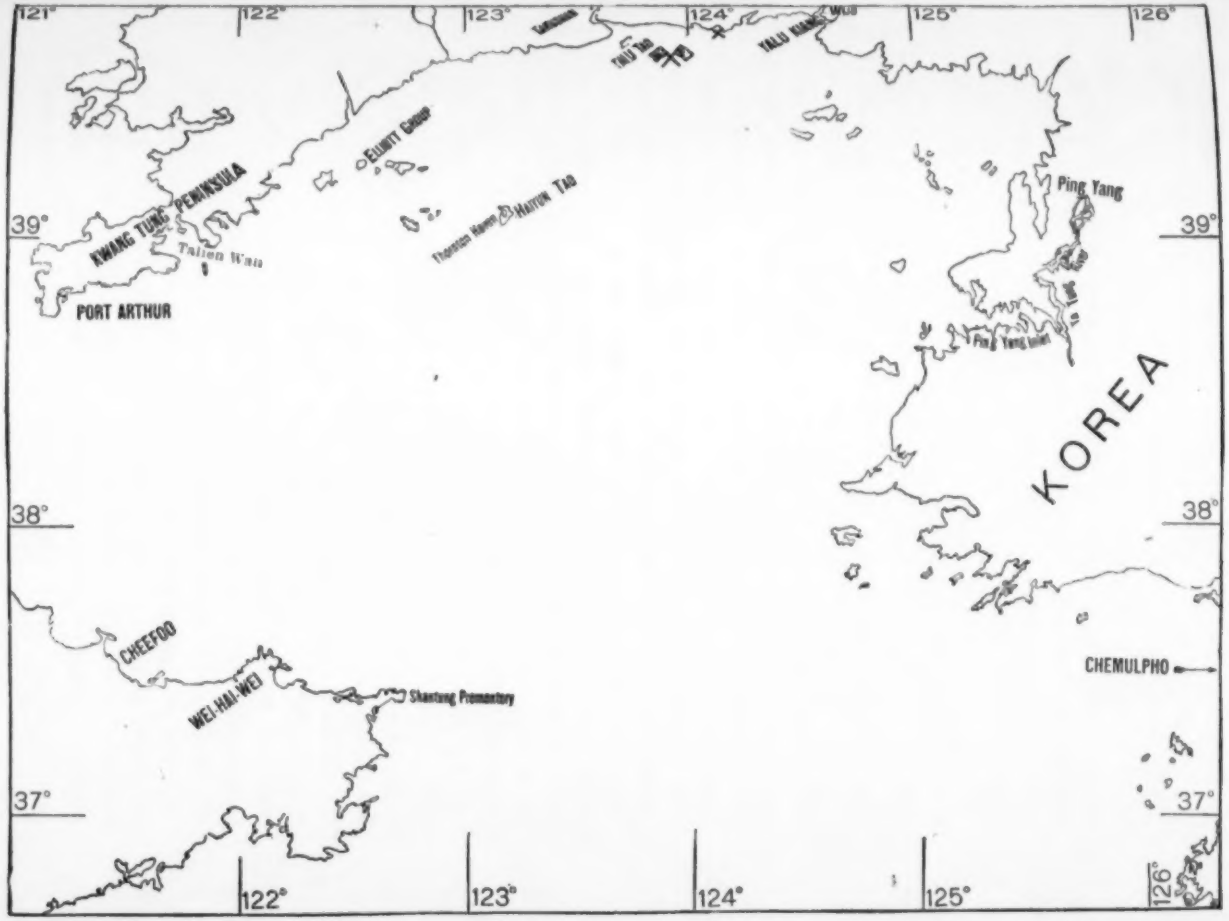
*Later reports seem to indicate that the troops were landed in the inlet west of the Yalu, where the fleet was found by the Japanese.

had gone northward to a "temporary anchorage" or rendezvous, whose exact position is not given, but which must have been in the eastern part of the Bay of Korea, some distance to the southward of the Yalu. At 5 p. m. on the 16th, the fleet, under Admiral Ito, sailed from this anchorage in search of the Chinese, steering for the island of Hai Yun, which is nearly in the course from Port Arthur to the Yalu and about midway between the two. At 6.30 a. m. on the 17th this island was reached, and the Akagi sent forward to reconnoitre the inner harbor of Thornton Haven. Finding no enemy the fleet steered for Talu Tao, off Taku Shan, 45 miles northeast of Hai Yun Tao and 40 miles westward of the Yalu, which island was sighted on the port bow at 10 a. m. Between 11 and 11.30 the van division signaled smoke to the east-northeast; and a few minutes past noon, the enemy having been recognized, the signal was made to prepare for action.

The Chinese opened fire at 10 minutes before 1, at a distance of 5000 or 6000 meters.

The first reports gave the position of the Chinese fleet across the mouth of the Yalu river; but later information, corroborating the inference from the times and distances just given, shows that it was lying in Takuo-hoa, or Taku-chad, or Ta-Tau-K'ou Bay, or inlet,—which is not marked on the Intelligence Office chart, but the position of which is given in Lat. 39° 47′ N., Long. 124° 7′ E.; that is, on the coast of Manchuria about 15 miles east of the Talu Tao and nearly 25 miles west of the Yalu. This position is marked on the accompanying chart by a cross. At the approach of the Japanese fleet the Chinese steamed out to meet them. The battle was fought in the open sea, and there is no reason to believe that either fleet was hindered in its manœuvring by shoals; nor was the Chinese, as was first stated, hampered by the presence of its transports. The sky was overcast, the sea rough, and the wind fresh from the east.

The composition of the two fleets is given in the following tables, which are taken from a paper by Secretary Herbert in the *North American Review* for November. Two ships omitted from the list of the Chinese fleet have been inserted in the table, and a column added giving the secondary batteries of the ships. These tables are based upon the publications of the Office of Naval Intelligence, and give the most accurate description of the ships


121°
122°
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39°
38°
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ELLIOTT GROUP
KWANG TUNG PENINSULA
Talien Wan
PORT ARTHUR
Thornton Haven
Hairon Tao
Ping Yang
KOREA
CHEEFOO
WEI-HAI-WEI
Shantung Promontory
CHEMULPHO

that has been printed. It may be noted that all the English papers, following the repeated inaccuracies of Brassey's *Naval Annual* for 1892, 1893 and 1894, give the Akitsushima the same battery as the three sister-ships Itskushima, Matsushima, and Hasidate; and their enumeration of the guns of the Japanese fleet is consequently erroneous. The tables in the *Army and Navy Gazette* contain besides some typographical errors. There is of course considerable diversity in the spelling of the names. Most of the English papers spell Chi Yuen "Tsi Yuen." The spelling here followed is that adopted by the Intelligence Office.

In addition to the ships given in the tables, the Chinese had three or four torpedo-boats (one report says that only one of these took part in the action), besides two 65-ft. boats hoisted on board each of the two battleships; and the Japanese had an armed mail steamer, the Saikyo Maru, in which Admiral Kabayama, of the naval general staff, was embarked on a tour of inspection.

It is not easy to estimate the relative strength of two such heterogeneous fleets. In numbers the Chinese were 12 to the Japanese 11. Considering that the little Akagi, with her two guns, is not much more than half the size of the smallest of the Chinese ships, and that she had no regular place in the formation, the slight numerical superiority of the Chinese is more marked. As to size, although the biggest two Chinese are bigger than the biggest three Japanese ships together, the average size of the Japanese ships is larger, and the total displacement of their 11 is greater than the total of the Chinese 12. In speed the Japanese had a great advantage. The figures in the table are maximum trial speeds, and it is not likely that either fleet attained its maximum in the engagement, but the figures may serve for comparison. The *average* of the Chinese fleet is 16 knots, the Japanese 17. The Japanese had three slow ships, the Fuso, Hiyei and Akagi, of 13 to 14 knots maximum, which were put in the rear of their column, and Admiral Ito did not always wait for them; the remainder of his fleet could go 16 knots or better, and his van was led by one of the fastest ships in the world. The Ping Yuen of the Chinese fleet had a maximum of only 10.5 knots, and even if she were left out—she seems to have played but a small part in the action—the remainder of the fleet could not keep more than 15 knots together. Considering that with the exception of the slow Ping Yuen and

CHINESE SHIPS ENGAGED IN THE ACTION OFF THE YALU RIVER.

Name.	Class.	Displacement, tons.	I. H. P.	Main Batteries.		Secondary Batteries.	Torp. tubes.	Armor.			Max. speed, knots.	Completed.
				No. and class of guns.	Total wt. of fire, lbs.	No. and class of guns.		Hull.	Battery.	Deck.		
a Chen Yuen...	Battleship	7,430	7,300	IV. 12.0″ B. L. II. 6.0″ B. L.	3,126	VIII. H. R. C. II. 3″.....	3	Belt, Partial, 8–14″	Barbette, 12″	2–3″	15.5	1883, Germany.
b Ting Yuen...	Battleship	7,430	7,200	IV. 12.0″ B. L. II. 6.0″ B. L.	3,126	VIII. H. R. C. II. 3″.....	3	Belt, Partial, 8–14″	Barbette, 12″	2–3″	15.4	1883, "
c King Yuen....	Coast defense vessel	2,900	5,000	II. 8.3″ B. L. III. 6.0″ B. L.	954	VII. H. R. C.....	4	Belt, Partial, 5.25–9.5″	.....	.....	15.0	1887, "
d Lai Yuen.....	Coast defense vessel	2,900	5,000	II. 8.3″ B. L. III. 6.0″ B. L.	954	VII. H. R. C.....	4	Belt, Partial, 5.25–9.5″	.....	.....	15.0	1887, "
e Ping Yuen....	Coast defense vessel	2,600	2,400	I. 10.2″ B. L. II. 6.0″ B. L.	637	VIII. R. F. G.....	4	Belt 8″	Turret, 5″	2″	10.5	1890, Foochow.
f Chi Yuen.....	Coast defense vessel	2,355	2,800	II. 8.3″ B. L. I. 6.0″ B. L.	730	VIII. H. R. C. II.—.....	4	4″ steel coffer-dams	Barbette, 15″	1.5–3″	17.5	1884, Germany.
g Chih Yuen....	Protected cruiser	2,300	6,000	III. 8.3″ B. L. II. 6.0″ B. L.	1,124	VIII. 6-pdr. R. F. G. II. Gat....	4	.....	.....	2–4″	18.5	1887, England.
h Ching Yuen..	Protected cruiser	2,300	6,000	III. 8.3″ B. L. II. 6.0″ B. L.	1,124	VIII. 6-pdr. R. F. G. II. Gat....	4	.....	.....	2–4″	18.5	1887, "
i Yang Wei....	Gunvessel	1,350	2,800	II. 10.0″ B. L. IV. 4.7″ B. L.	1,180	IV. H. R. C. II. Nord II. 9-pdrs. IV. Gat.	3	.....	.....	Partial 2–5″	16.2	1881, "
j Chao Yung...	Gunvessel	1,350	2,800	II. 10.0″ B. L. IV. 4.7″ B. L.	1,180	IV. H. R. C. II. Nord II. 9-pdrs. IV. Gat.	3	.....	.....	Partial 2–5″	16.2	1881, "
k Kuang Ting..	Gunvessel	1,030	2,400	III. 4.7″ B. L.	138	XII. R. F. G.....	4	.....	.....	1″	16.5	1892, Foochow.
l Kuang Ki....	Gunvessel	1,030	2,400	III. 4.7″ B. L.	138	XII. R. F. G.....	4	.....	.....	1″	16.5	1892, "
Total, 12...		34,975	52,100	12.0″ = 8 10.2″ = 1 10.0″ = 4 8.3″ = 12 6.0″ = 17 4.7″ = 14 Total = 56	14,411	H. R. C.....46 R. F. G.....48 Gatlings.....12 Nordenfeldt..... 4 9-pdrs., 3″, etc.....10 Total = 120	44					

JAPANESE SHIPS ENGAGED IN THE ACTION OFF THE YALU RIVER.

Name.	Displacement, tons.	Class.	I. H. P.	Main Batteries.		Secondary Batteries	Torp. tubes.	Armor.			Max. speed, knots.	Completed.
				No. and class of guns.	Total wt. of fire, lbs.	No. and class of guns.		Hull.	Battery.	Deck.		
1 Matsushima..	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XII. 4.72″ R. F.	1,416	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	.....	Barbette turret, 11.8″	1.5–2″	16.0	1891, France.
2 Itsukushima.	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XI. 4.72″ R. F.	1,370	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	.....	Barbette turret, 11.8″	1.5–2″	16.8	1891, "
3 Hasidate.....	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XI. 4.72″ R. F.	1,370	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	.....	Barbette turret, 11.8″	1.5–2″	16.0	1894, Japan.
4 Fuso.....	3,717	Armored cruiser	3,500	IV. 9.5″ B. L. II. 6.8″ B. L.	1,460	V. Nord. 1″. II. B. L. R.....	..	Belt, 8–9″	9–8″	.....	13.2	1878, England.
5 Chiyoda.....	2,450	Armored cruiser	5,600	X. 4.72″ R. F.	460	XIV. 3-pdr. R. F. G. III. Gat.....	3	Partial belt, 4.6″	.....	1–2″	19.0	1890, "
6 Hiyei.....	2,250	Armored cruiser	2,490	III. 6.8″ B. L. R. VI. 6.0″ B. L. R.	1,028	IV. Nord. 1″	2	Partial belt, 4″	.....	.....	14.0	1878, "
7 Naniwa.....	3,650	Protected cruiser	7,235	II. 10.2″ B. L. R. VI. 6.0″ B. L. R.	1,499	II. 6-pdr. X. Nord. 1″. IV. Gat...	4	....	.....	2–3″	18.9	1886, "
8 Takachiho...	3,650	Protected cruiser	7,500	II. 10.2″ B. L. R. VI. 6.0″ B. L. R.	1,499	II. 6-pdr. X. Nord. 1″. IV. Gat...	4	.....	.....	2–3″	17.9	1886, "
9 Yoshino.....	4,150	Protected cruiser	15,000	IV. 6.0″ B. L. R. VIII. 4.7″ R. F.	760	XXII. 3-pdr. R. F. G.....	5	.....	.....	1.75–4.5″	23.0	1893, "
10 Akitsushima.	3,150	Protected cruiser	8,400	IV. 6.0″ B. L. R. VI. 4.7″ R. F.	670	X. 3-pdr. R. F. G. several machine guns.	4	.....	.....	2–3″	19.0	1894, Japan.
11 Akagi.....	614	Gunvessel	700	I. 8.2″ B. L. R. I. 4.7″ R. F.	354	II. Nord. 1″.....	..	.....	.....	.....	13.0	1890, "
Total, 11...	36,462		66,025	12.6″ = 3 10.2″ = 4 9.5″ = 4 8.2″ = 1 6.8″ = 5 6.0″ = 26 4.72″ = 59 Total ..102	11,886	6-pdr. R. F. G.....22 3 pdr. R. F. G.....82 Nordenfeldt.....31 Gatling.....11 Machine guns, etc.....15 Total.....161	34					

the two small gunboats, built at Foochow in 1890 and 1892, all the Chinese ships were completed in 1887 or earlier; and that of the Japanese, with the exception of two old ships—Fuso and Hiyei—built in 1878, two were completed in 1886 and the rest all since 1890; and remembering that the Japanese ships are kept in much more efficient condition than the Chinese, and are better manned; it is probably not too much to say that Admiral Ito had an advantage in speed over Admiral Ting of at least 2 knots with the main division of his fleet, and not less than 5 with his swifter van.

Comparing now the armaments and armor of the two fleets:—the Japanese had nearly twice as many guns in their main batteries as the Chinese; but the Chinese had more heavy guns and could discharge considerably greater weight of metal at a broadside, though much less in a given time. In estimating the relative value of the two batteries on a particular occasion, the armor opposed to them must of course be taken into account. A more detailed comparison of the calibers may be made as follows:—

Guns.	10″ and over.	Below 10″, over 6″.	6″ and 4.7″.
Chinese,	13	12	31
Japanese,	7	10	85

Of guns fit to pierce heavy armor the Chinese had 13 to the Japanese 7. But the Japanese had no heavy armor to be pierced, except the turrets of the three sister coast defense vessels (so called), and the slow old Fuso. The Chinese, properly speaking, had only two heavily armored ships. There were, it is true, the Chi Yuen, with a 15″ barbette and no other armor, the King Yuen and Lai Yuen with 8″ turrets and belts of 9½″ to 5¼″—but only partial belts extending only 2 feet above water,—and the wretched little Ping Yuen, with her 8 inches of armor, 10½ knots speed and 3 guns;—but what sort of armored ships were they? In guns able to pierce lighter armor the two fleets were nearly equal. Of the smaller calibers the Japanese had almost three times as many; and moreover, all their 4.7″ guns and none of the Chinese were rapid-fire guns. In secondary batteries the superiority of the Japanese was even more marked. They had in all 161 guns to the Chinese 120.

	6-pdr. and 3-pdr. R. F. G.	H. R. C.	Gatling and Nordenfeldt.	Misc.
Chinese,	48	46	16	10
Japanese,	104	..	57	..

Of these, 104 were 6-pdr. and 3-pdr. rapid-fire guns, and 57 Gatling and Nordenfeldt machine-guns. The Chinese had only 48 rapid-fire guns and 16 Gatlings and Nordenfeldts, and also 46 Hotchkiss revolver cannon and 10 miscellaneous light guns, which last were boat howitzers, etc., and probably were not used at all. The Japanese had very few guns able to do any serious harm to the two heavy Chinese ironclads, but on the other hand it cannot be doubted that the Chinese would have been better off had all the heavy guns in their smaller ships been replaced by lighter quick-firing pieces.

In torpedoes the Chinese were decidedly superior, having 44 tubes to their enemies' 34, besides 4 torpedo-boats. It is open to question, however, whether they had that many tubes or torpedoes ready for action.

On the whole, considering the adversaries to which they were opposed, it is the opinion of the writer that the Japanese fleet, although none of its ships were quite a match for the best two Chinese, was decidedly superior in strength.

The following plans of the action are made up chiefly from Admiral Ito's report as published in the *Japan Mail*, Oct. 11. They differ somewhat from the plans given by Lieutenant Naoki Miyaoka, the Japanese naval attaché at Washington, in the *New York Times*, Dec. 9, which are the same as those in the *New York Herald* of Nov. 7, taken from the *Jiji-Shimpo* of Tokyo of Oct. 2. A good deal has to be left to conjecture. No attempt is made here to represent the manœuvres in the last part of the action. The order of the ships in the Chinese formation, as well as the formation itself, can only be taken as approximate. The two gunboats, Kuang Ting and Kuang Ki, and perhaps the Ping Yuen, probably reached their stations some time after the action had begun. The order of the Japanese ships in column is more nearly certain. The Naniwa may have been the fourth ship instead of the second, and the Chiyoda may have been next astern of the flagship; but these differences are immaterial.

The Chinese fleet, as it steamed out to meet its fate, formed in an irregular line, or crescent, or double echelon, or V, or "two

converging columns," according to the various accounts, which all agree that it was in great disorder. The actual formation probably was not the result of deliberate choice, but the order in which the ships found themselves in their unskillful attempt to get into some sort of line abreast. The battleships Ting Yuen and Chen Yuen were in the centre, flanked by the Lai Yuen and King Yuen, with the weakest vessels on the flanks. The Japanese fleet advanced in single column. The van division, commanded by Admiral Teuboi, was composed of the swift protected cruisers Yoshino, Naniwa, Takachiho, and Akitsushima. Then came the flagship Matsushima and her two sisters, then the Chiyoda, Fuso and Hiyei. The Akagi and Saikyo Maru were at first on the flank of the centre and rear divisions of the fleet; but the Saikyo, being ordered to avoid fighting, dropped to the rear,—though she afterwards joined in the battle,—and the Akagi, unable to keep up, was left behind.

The Japanese column first steered for the centre of the enemy's line, then gradually changed course to port, so as to come into action with its right wing. The Chinese opened fire at very long range; the Japanese replied at 3000 meters. The battle was fought in general at ranges from 2000 to 3000 meters. The Japanese van passed around the Chinese right flank and along their rear, apparently increasing its distance from the centre and rear divisions, which, led by Admiral Ito's flagship, performed the same manœuvre, defiling past the enemy's front as the van enveloped his rear. The Chinese order was thrown into great confusion, their right wing attacked on both sides by the whole of the Japanese fleet, their left out of action altogether. Admiral Ting's flagship and her sister ironclad headed for the enemy's centre, endeavoring to keep bows on, while the rest of the fleet steered in different directions, as if to engage separate vessels. Both sides kept up a hot fire.

As the Japanese centre and rear divisions passed in turn around the Chinese flank, their slowest ships, the Fuso and Hiyei, came within shorter and shorter range; and finally the captain of the Hiyei, which brought up the rear, seeing that by holding his course he could not clear the enemy's line, boldly steered between the two Chinese battleships, passed through their line, receiving and returning their fire, and rejoined his squadron on the opposite

EXPLANATION ON THE FIGURES.

In each of these figures, two successive positions of the fleets are represented. The first position is shown by outlined, the second by shaded and solid ships, the Japanese ships being shaded and the Chinese solid. The first position in Fig. 2 is the same as the second in Fig. 1. The ships are numbered and lettered to correspond with the list in the foregoing tables, as follows:

JAPANESE.

1. Matsushima (flag).
2. Itsukushima.
3. Hasidate.
4. Fuso.
5. Chiyoda.
6. Hiyei.
7. Naniwa.
8. Takachiho.
9. Yoshino.
10. Akitsushima.
11. Akagi.
12. Saikyo Maru.

CHINESE.

a. Chen Yuen.
b. Ting Yuen (flag).
c. King Yuen.
d. Lai Yuen.
e. Ping Yuen.
f. Chi Yuen.
g. Chih Yuen.
h. Ching Yuen.
i. Yang Wei.
j. Chao Yung.
k. Kuang Ting.
l. Kuang Ki.

The four ships in the upper right-hand corner of Fig. 2 represent the Akagi chased by three Chinese ships, and of course this part is not simultaneous with the rest of the figure.

FIG. 1.

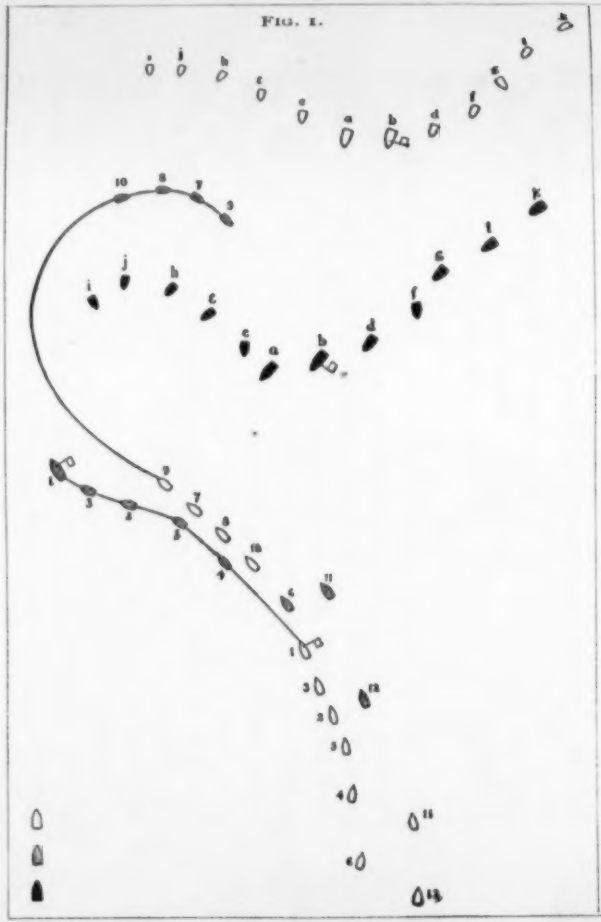
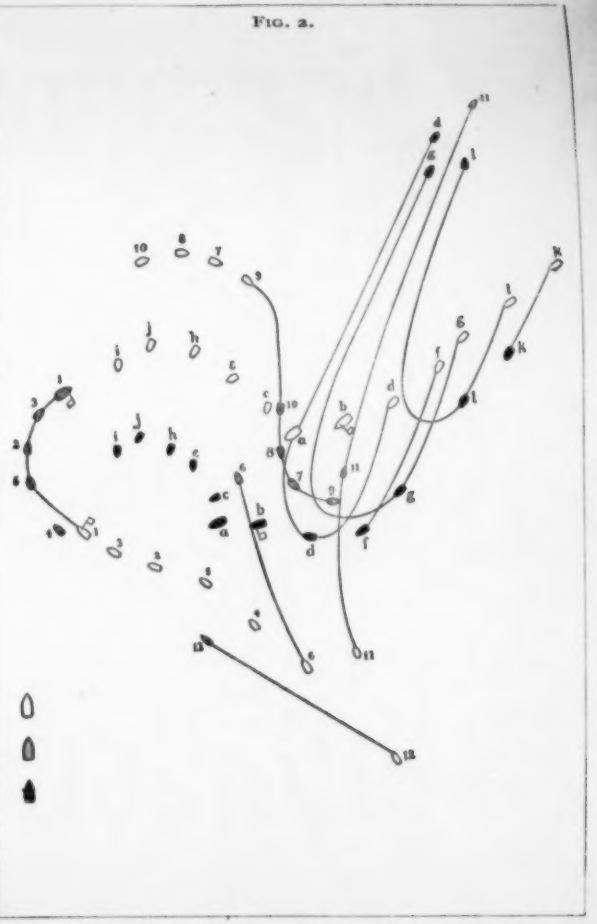


FIG. 2.



side. The little Akagi also appears to have broken through the enemy's line, somewhere to the left of its centre; and three Chinese ships passed under her stern within 800 meters. A shell struck her bridge, killed the captain and several men, and wounded several others; her forward magazine was destroyed and a steam pipe shattered. The first lieutenant took command of the ship. The Japanese van division, headed by the Yoshino, then, seeing the peril of the Hiyei and Akagi, instead of leading down the enemy's rear, changed course more to starboard and steamed at full speed to the rescue, pushed between the Akagi and her assailants, pouring their starboard broadsides into the latter as they passed. This again enveloped the Chinese right wing between two fires. [At this point the plans here given differ from those of Lieutenant Miyaoka and the *Jiji-Shimpo*. The latter represent the van division turning with starboard helm, and passing a second time entirely around the Chinese right flank, outside and in opposite direction to the Japanese centre division. The plan here given (which was made before these two were published) is believed to represent the movement more truly. Otherwise the van of the Japanese fleet must have been separated for a considerable time from the Chinese by its own centre and rear divisions, and must have turned its port broadsides toward the enemy. Whereas Admiral Ito explicitly says the Hiyei had passed through the Chinese line, and his van went to rescue her as well as the Akagi, and poured in their starboard broadsides as they passed, and "thus the enemy was placed between the fires" of the two divisions.]

The Hiyei about this time signaled that she had taken fire, and together with the Akagi retired from the action. Three Chinese ships, the Lai Yuen, Chih Yuen and Kuang Ki, pursued first the Hiyei and then the Akagi; but that brave little ship, in spite of the damage to her steam pipe, managed to keep ahead of them, working her stern gun with the utmost rapidity and with good effect. The commanding officer of the Akagi went into the maintop to look out for torpedo-boats, and signaled their movements by flags to the other ships. The Lai Yuen got within 300 meters; a shell from her struck the Akagi's bridge and wounded the navigator, who resumed his post as soon as his wounds were dressed; several shots hit her mainmast and finally brought it down, killing the commanding officer and two men on the lookout aloft; but at last

a shell from the Akagi's stern gun set her pursuers' quarter-deck on fire, and in the midst of the confusion the other two Chinese ships stopped to succor her, and the Akagi escaped. After repairing her steam pipe she rejoined the fleet three or four hours later.* The Chih Yuen returned to the battle-ground; the Lai Yuen was too much damaged to take any further part in the fight; and the Kuang Ki was not heard of more.

There is some mention in one or two accounts of the Chinese fleet being reinforced in the midst of the action, and Admiral Ito states the numbers reported to have joined the enemy at this time as six torpedo-boats and four men-of-war. It is doubtful if so many joined, as their names are not given and there is no more detailed account of their part in the action, the course of which they certainly did not affect. If men-of-war, they were probably one or two of the small alphabetical gunboats. It is more probable that two or three of the Chinese fleet were so far behind in coming into action as to be mistaken by Admiral Ito for reinforcements, for he gives the original force of the Chinese ten ships instead of twelve.

In the meantime the centre and right of Admiral Ting's fleet continued in hot action. Admiral Ting was wounded 20 minutes after the fight began, in the following peculiar manner: He is reported to have been standing on the bridge, and to have been warned that he was in a dangerous place, but refused to move. One of the barbette guns when trained across came under the bridge; the admiral was thrown in the air, his right leg hit by splinters, and his face burnt. Commodore Liu Tai Tsan then took

*It is uncertain whether both the captain and the first lieutenant or only the captain of the Akagi was killed. The "report of the Akagi" in the *Japan Mail* says that the captain was killed at 1.25 p. m. by a shell striking the bridge, but makes no mention of either the captain or first lieutenant being aloft and being killed by the fall of the mast, which happened some time later; but it mentions the name of the lieutenant who "took the place of the navigating officer and commanded the vessel" (for 8 minutes, from 2.15 to 2.23) while the latter was having his wounds dressed. The report of Admiral Ito's aide-de-camp to the Mikado, on the other hand, says that the captain was aloft and was killed by the fall of the mast, and that the first lieutenant then took command. The lists of casualties published in the *Army and Navy Gazette* credit the Akagi with only one officer killed.

command of the fleet.* All four—or possibly only two—of the Chen Yuen's heavy guns—which are mounted in pairs, covered only by $\frac{1}{8}$" hoods, within an irregular shaped barbette redoubt—were knocked out of service early in the fight, apparently by a single lucky shot; and she was reduced to the two 6" guns in the bow and stern.

The Yang Wei and Chao Yung, which occupied the extreme right of the line, where they received the fire of the whole Japanese fleet in passing, were by this time out of action,—the former retiring slowly shorewards in the direction of Talu Tao, the latter run upon a rock,—both enveloped in flames. Finally the Yang Wei was beached; and the Chao Yung, settling aft, went down in deep water, her upper masts remaining above the surface. Her miserable crew took refuge in the rigging, but the battle was too furious for friend or foe to heed their cries. The Kuang Ting also, from her position in the left wing, passed by the Chinese flagship and fled toward the shore. The Chi Yuen also withdrew early in the day, all three of her gun carriages having got out of gear, though not from any damage by the enemy's fire.

The descriptions of the manœuvres in the latter part of the action are extremely vague. It is evident that the Chinese order was thrown into entire confusion. Admiral Ito's main division, keeping its formation of single column to the last, is reported to have circled around what was left of the Chinese fleet, and even to have repeated the manœuvre three times. After a time the Chinese flagship tried to close, apparently with a view to ramming. She broke the formation and with two or three other ships charged at full speed. Admiral Ito reports that at half past two the Ting Yuen steamed past the front of his squadron,—"but she received such a storm of projectiles that her crew seemed to fall into a state of the greatest confusion, and presently she took fire." The King Yuen also was severely crippled in the attempt. The enemy's fire was concentrated upon the disabled ships and especially upon her. She tried to escape, but the Japanese van gave chase, leaving the main division engaged with the sister ironclads. Finally the King Yuen was sunk. Her gunners remained at their pieces

*He it is that has since committed suicide in consequence of having stranded the Chen Yuen in attempting to avoid the submarine mines in the harbor of Wei-Hai-Wei.

until the last minute. She went down slowly, stern first; her bow rose out of the water, remained a minute and a half in that position, then disappeared forever. In the Japanese fleet "the enthusiasm was indescribable, the crews redoubled their ardor, the officers exulted in satisfaction."

About this time the Chih Yuen, which had returned from the chase of the Akagi, went down with all on board. The manner of her loss is uncertain. According to the first reports of the Chinese, her captain, who had several times disregarded the Admiral's signals, deliberately steamed out of line, rammed and sank a Japanese ship, and in so doing received such injuries to his own ship that she also went down. This is very doubtful, for the Japanese official reports make no mention of any of their ships being rammed, and it is certain none of them was sunk. The earlier reports mentioned a second armed merchantman, besides the Saikyo Maru, and it has been conjectured that this might have been the ship sunk. It is much more probable that no such ship was present. The later Chinese reports say the Chih Yuen was sunk by gun fire, and went down bow first, screws revolving.

At half past three, when the two flagships were in close range, the Matsushima's turret was struck by a 12" shell, which did great damage and set the deck on fire, though apparently it did not penetrate the armor. Another shell exploded aboard the Matsushima, dismounting the forward 4.7" rapid-fire gun and killing a number of men. The gun was hurled violently across the ship. The Japanese flagship had been from the first the object of the Chinese' special attentions; her commander and first lieutenant were killed, 120 men either killed or wounded. Admiral Ito then, like Commodore Perry at Lake Erie, transferred his flag to the Hasidate.

About this time—3.30 p. m.—it is reported that firing ceased on both sides, many of the ships, especially the Chinese, being on fire. The action recommenced at about 4.30, by the five ships of the Japanese main division again attacking the two Chinese battleships. Firing finally ceased at six.

The whereabouts of the Hiyei and Saikyo Maru were then uncertain. The former, on fire, had retired as already described. A torpedo fired at her missed. She suffered severely from shells, and one exploding in the officers' quarters killed two surgeons, several nurses, and many men already wounded. The fire was

finally got under control. She went to the rendezvous and removed her wounded to a transport next morning, then sailed in company with the Kaimon to the scene of the battle, at which the latter had not been present, and returned to rejoin the fleet on the 20th.

The Saikyo had also taken some part in the fight and got roughly handled. She first opened fire at long range, and later got to close quarters with the Chinese ironclads. After an hour or more her steering gear was disabled and she retired, attacked or chased for awhile by the Ping Yuen and one of the smaller Chinese vessels and two or three torpedo-boats. Two torpedoes were fired at her and missed, one of which, discharged from a distance of 40 or 50 yards, passed under her bottom. The Saikyo returned to the rendezvous early the following morning.

Falling darkness ended the battle. Admiral Ting gathered the remnants of his fleet and steered—as afterwards appeared—for Port Arthur. Admiral Ito recalled his van division and shaped a course supposed to be parallel to that of the Chinese squadron, which was standing to the southward, apparently for Wei-Hai-Wei. Speed was reduced to that of the slowest injured ships, and the fleet separated from the Chinese as a precaution against torpedo-boats. During the night, which was dark, the enemy was no longer in sight.

Admiral Ito steamed southward until dawn, hoping to intercept the Chinese off Wei-Hai-Wei. Not finding them, he ordered the Akagi to proceed to the rendezvous, returned with the rest of the fleet to the scene of the action, and there discovered the Yang Wei, beached and deserted. The Chiyoda blew her up with a torpedo,—the only one fired by the Japanese. Thence the fleet went to the rendezvous or "temporary anchorage," where it arrived early on the morning of the 19th, found the Akagi and Saikyo Maru, and next morning was joined by the Hiyei and Kaimon.

Later reports state that the Kuang Ki, having made her escape early in the battle, after the chase of the Akagi, ran on the rocks in Talien Wan while making for Port Arthur. There she was discovered, apparently some days later, by the Naniwa and Akitsushima; and her crew, seeing the cruisers, set fire to her and fled. The Japanese completed her destruction.

By the latest accounts the Chinese lost five ships, and at least

two others were disabled. The Chao Yung, King Yuen and Chih Yuen were sunk; the Yang Wei and Kuang Ki were run ashore and subsequently destroyed. The Chen Yuen and Lai Yuen were totally disabled.

The Ting Yuen is reported to have been struck by no fewer than 200 projectiles, but her armor was not seriously damaged. The deepest dents were about three inches. Her upper deck was entirely destroyed by fire; two of the secondary battery guns were disabled; all the signal halliards were shot away; but the engines were uninjured. The Chen Yuen was hit fewer times—120—but her injuries were even more serious than the flagship's. Her main battery was crippled; she is reported to have reached the anchorage almost sinking, about three feet down by the head. The Lai Yuen suffered most from fire. She was gutted fore and aft; the deck and bulkheads about the magazine became red hot. The Ping Yuen, according to Admiral Ito's report, suffered severely from fire; according to others she took little part in the action. The Ching Yuen also is reported to have been badly hulled.

Of the entire fleet only three—not counting the Ping Yuen—escaped without very serious injury,—namely, the Ching Yuen, Chi Yuen and Kuang Ting. And of these three, two—the last named—had run away; as did at least one other. The captains of the Chi Yuen and Kuang Ki have since, in consequence, been beheaded.

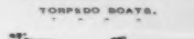
As for the Japanese, three ships—the Matsushima, Hiyei and Akagi—and also the Saikyo Maru, were more or less severely injured; and of these the two small ships and the armed transport were driven out of action. All the rest were injured very slightly or not at all. The Yoshino, in coming to the rescue of the Hiyei and Akagi, was struck several times and sustained some damage to one of her forward sponsons, which was repaired on the spot. The Matsushima had to be sent to Japan; the others were repaired by their own hands.

With regard to the loss of life, there is the same appalling inequality. The Chinese casualties are variously stated, from 700 killed and 250 wounded, to 1500 altogether, including the men lost in the ships sunk. Several of the foreigners serving in the Chinese fleet were killed. The Japanese loss, according to the highest figures in any of the reports, was 10 officers and 84 men

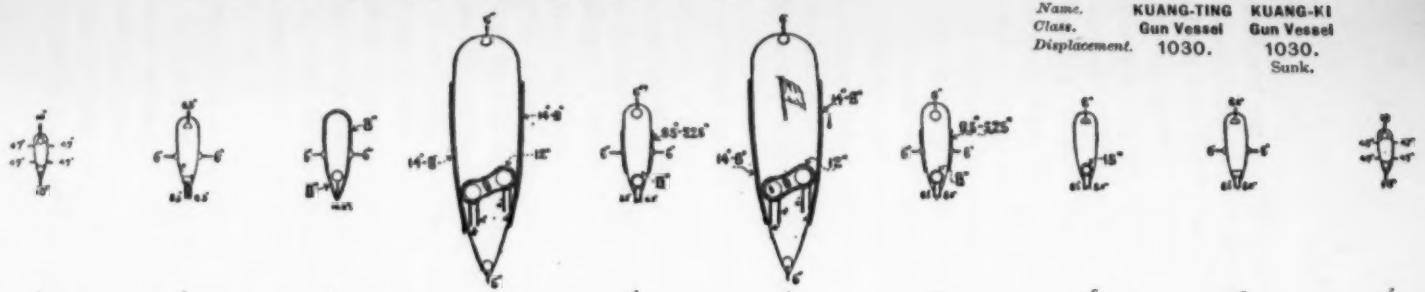
COMPARISON OF VESSELS ENGAGED.

BATTLE OFF YALU RIVER, SEPT. 17, 1894.

TORPEDO BOATS.

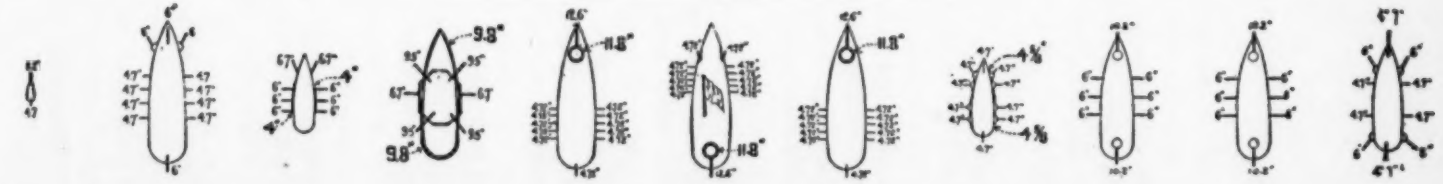


	k	*l*
Name.	KUANG-TING	KUANG-KI
Class.	Gun Vessel	Gun Vessel
Displacement.	1030.	1030. Sunk.



	j	*h*	*e*	*a*	*d*	*b*	*c*	*f*	*g*	*i*
Name.	CHAO YUNG	CHING YUEN	PING YUEN	CHEN YUEN	LAI YUEN	TING YUEN	KING YUEN	CHI YUEN	CHIH YUEN	YANG WEI
Class.	Gun Vessel	Protected Cruiser	Coast Defense Vessel	Battle Ship	Coast Defense Vessel	Battle Ship	Coast Defense Vessel	Coast Defense Vessel	Protected Cruiser	Gun Vessel
Displacement.	1350. Sunk.	2300.	2600. Injured. (?)	7430. Disabled.	2900. Disabled.	7430. Badly injured.	2900. Sunk.	2355.	2300. Sunk.	1350. Sunk.

CHINESE FLEET.



	11	9	6	4	2	1	3	5	7	8	10
Name.	AKAGI	YOSHINO	HIYEI	FUSO	ITSUKUSHIMA	MATSUSHIMA	HASIDATE	CHIYODA	NANIWA	TAKACHIHO	AKITSUSHIMA
Class.	Gun Vessel	Protected Cruiser	Armored Cruiser	Armored Cruiser	Coast Defense Vessel	Coast Defense Vessel	Coast Defense Vessel	Armored Cruiser	Protected Cruiser	Protected Cruiser	Protected Cruiser
Displacement.	614. Injured.	4150.	2250. Injured.	3710.	4280.	4280. Badly Injured.	4280.	2250.	3650.	3650.	3150.

JAPANESE FLEET.

killed, and 160 officers and men wounded,—total 254. The greatest loss was aboard the flagship Matsushima.

Such were the incidents of this memorable battle, as far as the truth can be made out from the mass of incomplete and conflicting reports thus far published. Many criticisms of it have been written, opinions the most various and opposite expressed, and scarcely a theory of naval tactics or construction has not been held to have been either proved or disproved by it. In the humble opinion of the present writer, the moral of the tale is very plain.

With regard to construction, the most striking and important lesson undoubtedly is the liability of modern ships to injury from fire. Throughout the whole engagement conflagrations were raging, and the severest damage to both fleets was done by fire. It may be supposed that the Chinese, at least, made no efficient efforts to put out the flames ; but still the warning is unmistakable that men-of-war ought, if possible, to be built entirely of incombustible materials.

As to the relative advantages of different types of ship, this battle certainly did not prove that unarmored cruisers can stand up against battleships,—Lord Armstrong, the builder of the Piemonte, to the contrary notwithstanding. Rather quite the contrary, it proved, if it proved anything at all about the question, that heavy guns are necessary to attack heavy armor. Witness the battering of the Ting Yuen. It may be replied that the Chen Yuen's heavy guns were disabled by a single shot. The answer is not that she would have been better off without them in an action with another armored ship, but that heavy guns must be heavily protected. There is hardly a modern battleship afloat with her heavy guns so badly mounted, and without, in addition, a numerous secondary battery powerful enough to have silenced the Matsushima or Chiyoda. What this action did show regarding types is how much a fleet is handicapped by being composed of dissimilar ships. Even one or two discordant units, like the Akagi or Yang Wei, may cripple a line-of-battle.

It is to be regretted that the tactics of the battle are so imperfectly described. Enough is known however to justify certain broad conclusions. Admiral Ito, realizing his superiority in ordnance, wisely neglected his torpedoes and his rams, and formed his line-of-battle in the way to reap the fullest advantage from his

guns. Until more precise knowledge is available it is probably premature to say that the Japanese superiority in speed absolutely prevented the Chinese from closing to ram. But this much at least is certain, that if modern fleets are to follow the tactics of the Athenian triremes, it is absolutely essential that ships must move and turn in unison. The ridiculous performances of the Chinese torpedo-boats will not discourage the advocates of those auxiliaries in fleet actions. In the words of M. Weyl, "In skillful hands the torpedo sometimes misses; managed by Chinese, it is absolutely inoffensive."

All accounts of the damage suffered by the different ships go to show the tremendously destructive power of modern ordnance. It is worth noting that the Chinese reported that they suffered most from the small-caliber rapid-fire guns. This probably refers to injury to personnel. In gun practice as in ordnance the Japanese were far superior to their enemies. In the latter part of the battle the Chinese ships ran short of ammunition. The two ironclads fired 197 rounds from their 12" guns. We cannot tell from this precisely what the time between fires was, because the duration of the action is not exactly known, nor the time when the Chen Yuen's heavy guns were disabled, but it was probably from 5 to 6 minutes. If any deductions regarding weapons can be drawn from a battle between antagonists so unequal, they verify the predictions of Professor Alger: "A ship which, either improperly armed or manned with men insufficiently trained in gun practice, trusts to her torpedoes or ram and endeavors by them to gain the victory, will fall an easy prey to an antagonist in whose construction and tactics the gun is recognized as the paramount weapon." And, further, "power lies in broadside far more than in end fire."

We are not told what signals were made. The only ones mentioned in the Japanese reports were made before the action began, and after it had ended. On the Chinese side we hear of one captain repeatedly disregarding the admiral's signals, and of all the signal halliards being shot away. All accounts describe the ships of the Celestial Empire disordered and disorganized from the very first, the fleet of the Rising Sun manœuvring throughout with admirable precision.

In his conception of grand tactics, Admiral Ito proved himself immeasurably superior to the Mandarin who before this battle

had the reputation of an able admiral. It is impossible not to admire the mastery of the art he displayed, while at the same time one wishes he had had a foeman worthier of his steel. Admiral Ito's plan of battle appears to have been prearranged. In the words of the official report, "our fleet manœuvred so as to concentrate its fire on one flank of the Chinese squadron, then on the other." But whether preconcerted, or the inspiration of the moment, his plan to double on the weakest part of the enemy's line, in a manner virtually identical with that of Nelson at the Nile, was an application of the unchanging principles by which all battles have been won. It is very much to be doubted, on the other hand, whether Admiral Ting had any preconceived plan of action whatever. By his miserable formation he laid himself open to be beaten in detail. Had the Chinese fleet been capable of concerted movement, it is conceivable that by forming column, by "vessels right turn," before the Japanese van had passed around its wing, it might have frustrated Admiral Ito's plan and concentrated all its fires upon the head of the enemy's advancing column. Even after his flank had been turned, a bolder leader would have seized the opportunity to separate the two divisions of the Japanese fleet.

Not a little of the glory of the victory belongs to Admiral Teuboi, the second in command,—or to the captain of the Yoshino, whichever it was,—who with *coup d'oeil* worthy of Nelson at Cape St. Vincent, without waiting for orders, led the van away from the prescribed course to carry succor to the Hiyei and Akagi. If he did not actually save the day, at least he saved those two ships.

And "the conduct of our crews was above all praise." The commander-in-chief concludes his official report by saying: "One thing to be specially noted is that even the seamen, firemen and others—of course it is unnecessary to speak of the officers—discharged their duties with evident satisfaction, and preserved their presence of mind even when the enemy's fire was at its hottest and when their superiors and comrades were falling dead or wounded beside them. On this point there is remarkable unanimity among the reports of the various commanding officers." On the other side, what a contrast! Admiral Ting was as ill-supported as old Benbow. He is said to have conducted himself with "admirable

coolness," but his fleet acted like a scared flock. The shepherd knew not his sheep, and the sheep knew not their shepherd. Ship after ship under the yellow dragon fled toward the shore. Two captains have lost their heads for cowardice. The gunners of the King Yuen alone relieve the dismal story. Bravely indeed they fought, with the savage courage of despair, when no hope remained of either victory or flight.

If there is any criticism to be made of Admiral Ito, it is that he did not continue the battle to the bitter end. He had eight ships in fighting trim, while at the most five only remained of the Chinese fleet, and two of those were disabled. "Had we taken ten sail, and allowed the eleventh to escape, being able to get at her, I could never have called it well done." It is remarkable that not a single ship surrendered. Every one of the Chinese fleet either was sunk, or took to flight, or retired after the battle was over. The two battleships, the mainstay of the enemy's strength afloat, were still unconquered, and the demoralization of the Chinese, which Admiral Ito had witnessed, might have emboldened him to take greater risks. And it certainly was a blunder to lose touch with the enemy during the night. His apprehension of the Chinese torpedo-boats, which is the reason given, certainly was not justified by the experience he had had of them that day.

But this suggestion that Admiral Ito, having done well, might have done better still, is made with extreme deference. It must be borne in mind that we have as yet very imperfect knowledge of the operations of the war, and none whatever of the orders under which the admiral was acting. It may well be that Captain Mahan's comment upon the battle of Cape St. Vincent is perfectly applicable to the Yalu: "It has been thought that further pursuit of a fleet so disgracefully beaten would have increased the British triumph; but Jervis was not the man to risk a substantial success, securely held, for a doubtful further gain. The victory essential to Great Britain was won; the worthlessness of the Spanish navy was revealed,—it could no longer be counted a factor in the political situation. In the opinion of the author, Jervis was right not to expose this, the great and attained result of Valentine's Day, to those chances of mishap that cannot be excluded from the operations of war."

Upon Admiral Ting the following judgment, severe but just, has been written by M. Weyl: "Voilà des années qu'il commande la flotte de Petchili, et il n'a pas su constituer une force navale digne de ce nom! . . . Des mouvements de l'ennemi il ne savait rien, et s'il s'en inquiétait, c'était d'une façon toute platonique! L'amiral Ting s'est bravement conduit, mais le courage ne suffit pas à ceux qui ont le redoubtable honneur de commander en chef."

Any discussion of the strategy of the campaign belongs rather to the history of the war than to the story of a single battle. It may be remarked however, that whatever knowledge of strategy Admiral Ting may have had, he was bound hand and foot by the orders of the Tsung-Li Yamen. He is not the first admiral that has suffered from the meddling of cabinets. The same thing may be true of Admiral Ito. Otherwise the question arises: Would he not have rendered more effectual service by blockading the Chinese fleet and transports in Port Arthur and Talien Wan, after the manner of St. Vincent before Brest, than by guarding the flank of the army in the Ping Yang inlet? Once free, however, he moved with no uncertain steps and manifested an energy and forethought in bright contrast to the lethargy or indifference of Admiral Ting.

The battle of the Yalu, like the frigate actions of 1812, was won by the stronger fleet; but the loss inflicted was out of all proportion to the preponderance of material force. As history has again and again proclaimed, battles are not won by ships and guns alone, but by cool heads, trained hands, steady nerves and brave hearts. And this is the lesson of the Yalu.

Ships and guns, the best of their kind, Admiral Ito had; and the mere provision of such a fleet—in no small measure due to the personal influence of the Emperor himself—shows on the part of the government the same foresight that has characterized all the operations of this war. And the ships themselves were well equipped,—as anyone that has seen them can bear witness; while the Chinese, to cite only one example from a letter by the American commander of the Chen Yuen, were "badly fitted out in the surgeon's department, only two Chinese doctors to 20 ships and an army of 300,000 men." The Mikado's sailors kept their lamps trimmed and were ready when the bridegroom came; while the

subjects of the Son of Heaven, like foolish virgins, had let their oil run dry, and the crisis found them unprepared.

But not only was the Japanese fleet in a state of high efficiency; the personnel of every rank, by previous energetic training and hard study, was prepared for the day of battle. And when the great day came, the squadrons of evolution, which the Japanese have had ever since they have had a fleet, the naval manœuvres, which they have carried on for the last two or three years for periods of a month at a time, the study of naval tactics and the conduct of war, in which the admirals and captains took such pride,—all bore their just fruit. Can anyone doubt that, whichever fleet Admiral Ito and his captains and crews had fought, they would have won?

This Asiatic war, waged between two nations whom we newer western civilizations have been accustomed to regard as barbarians, has such transcendent interest to us, not because the battle of the Yalu, the first modern fleet action since Lissa, has settled any moot questions of naval tactics or naval construction; but because it has furnished a most striking exemplification of the everlasting truth, which all history has proved,—that training, organization, discipline, ésprit de corps—these are the begetters of victory.

"The gods all things on men bestow, at labor's price."

One word more. It is ludicrous to note how the French rejoice that some of the Japanese ships were designed by them; how the Germans congratulate themselves that the Japanese regimental organization was modeled after theirs; how the English, who seemed at first to be not a little chagrined that their friends the Chinamen were getting so badly beaten, now pat themselves on the back because they had a share in building the Japanese fleet, and set the fashion in uniforms; how we Americans take unto ourselves credit that some of the Japanese officers were trained at the Naval Academy; how all we foreigners congratulate the Japanese on their progress in European civilization and skill in European warfare. Let us rather acknowledge them masters of the art. Ships and guns and uniforms, elementary training and drill-books, indeed, they had of us; but these, as the Japanese call the Roman alpha-

bet, are but the "gateway to the kingdom of western knowledge." The principles of the art of war are catholic and eternal, and belong not to one nation nor to one age. The Japanese are a race of warriors and sailors, and trace back their martial inheritance from the long line of Shoguns, beginning with Yoritomo, and his brother who won the great sea fight near Shimonoseki seven centuries ago; from the famous Iyeyasu, first of the Tokugawa line; from the great general Hideyoshi, who invaded Korea three hundred years ago, and many more brave daimios and samurai who have made their names terrible in war, since the day when the first Mikado, Jimmu Tenno, descendant of the Sun-goddess, sailed up the Inland Sea.

DISCUSSION.

Lieutenant-Commander RICHARD WAINWRIGHT, U. S. N.:—The battle of the Yalu has been treated in a most satisfactory manner by Ensign Marble. He has arranged the data and adjusted the conflicting statements with skill and discrimination. I am glad he does not follow the plans of Lieutenant Miyaoka, I. J. N., who gives the distance between the divisions of the Japanese fleet, when advancing to the attack, as 4000 yards. From Mr. Marble's figure this distance appears to be about 1300 yards. This latter distance may be due to irregularity in formation; but it would be difficult to justify such a separation between divisions as 4000 yards with any tactical theory.

That the Japanese succeeded in doubling on the Chinese fleet is undoubted and according to Mr. Marble they doubled on the right flank of the Chinese fleet both in position and in succession. It is doubtful if this utilization of higher speed, which enabled them to double on the right wing in position but resulted in a further separation of the two divisions, would have been advisable against a more skillful enemy, but the doubling in succession was tactically sound.

The escape of the Hiyei and Akagi from total destruction, especially that of the former, which passed between the two battleships, illustrates the inefficient armament of the Chinese vessels. Had the battleships been properly armed with rapid-fire guns, and had they been decently served, the Hiyei must have been destroyed.

When the question of the Japanese fleet keeping in touch with that of the Chinese is considered, it must be remembered that the former fleet was composed of cruisers and that Admiral Ito would have been obliged to detach from his main fleet several of its units in order to maintain touch.

It would have been a questionable action for Admiral Ito, with only eight ships remaining, to have detached two or three of the eight to act as scouts. Had his fleet been one of battleships with a respectable allowance of cruisers, he would have been seriously in fault had he failed to keep touch with the Chinese.

The criticism of Admiral Ito for guarding the flank of the army in the Ping Yang inlet, in place of blockading the Chinese fleet in Port Arthur and Talien Wan, hardly seems well founded, and the comparison with Saint Vincent off Brest does not seem to be applicable to the condition of affairs immediately previous to the battle of the Yalu. Saint Vincent was guarding no specially weak point of his own forces. His object was to prevent the Brest fleet from engaging in any sea operations, particularly from combining with other French fleets. The escape of a few vessels was unimportant. As history shows is the correct practice, he drew the lines ot blockade close to the port. Ito had a specially weak point to guard, *viz.*, the transports that carried one portion of the army to Ping Yang, and the supply boats for the entire army. Even had the Japanese been of sufficient strength to blockade successfully the Chinese fleet, it would have been necessary to leave a guard of several vessels at the inlet in case of the escape of a small portion of the Chinese fleet. Then the eleven vessels of the Japanese were not a sufficient force to blockade the twelve Chinese vessels.

Where a whole coast or a great commerce must be protected from a fleet, it is sound strategy to blockade closely that fleet, for there being many weak points it is impracticable to guard all; but where there is one weak point it can be protected best by holding the force at or near the point. It was not sound strategically, landing a force with the Chinese force united, unbeaten and free to take the sea; of this history gives many illustrations; but one of the most frequent incidents in history shows the necessity of running risks in war and attempting undertakings, which, while not strictly correct according to the maxims of strategy, are justified by the governing conditions. Japan could not afford to arrest her advance upon the Korean frontier until her fleet was able to bring the Chinese fleet to action and defeat it. Admiral Ito felt strong enough to drive this fleet back and prevent them from disturbing the operations of the army.

The danger from a flanking fleet should not be exaggerated. It is most dangerous when the co-operating fleet is transporting troops, assisting with its guns, or otherwise hampered by the nature of the operations; then the attack of a flanking fleet is to be dreaded; but when all the troops are in transports, the landing is unopposed and the co-operating fleet untrammeled except by the obligation of a complete defense, the attack of an inferior or equal flanking fleet becomes an ordinary incident of war, the liability being no greater than usual although the consequences of defeat might be far more serious.

Lieutenant W. F. HALSEY, U. S. N.:*—Ensign Marble's most ably written article on the Yalu river fight has been read with great interest; but an intelligent criticism on its contents is impracticable. With the advantages to be gained by reading numerous reports of the engagement, coupled with conversations with officers of both sides that were engaged in the fight, and after seeing some of the injured vessels, there still remain so many conflicting conditions that a report compiled from newspaper descriptions must necessarily contain numerous inaccuracies. From information received on the station, some of the doubtful points under discussion may be made clearer, but an absolutely accurate description of the naval battle of Hiyang (Yalu) is yet to be written. The relative sizes of the two fleets as to tonnage, guns, and armor is practically established.

As a unit the speed of the Japanese fleet did not exceed 10 knots; for though the Akagi is quoted as a 12-knot vessel, 10 knots represented the best results from that gunboat under most favorable conditions. Individual ships of the Japanese were very fast, notably the Yoshino. The writer has seen this vessel make 19 knots with ease, when chasing torpedo-boats that had escaped from Wei-hai-wei. The formation of the Chinese fleet was that of an irregular double echelon on the battleships Ting Yuen and Chen Yuen in the center. The Japanese were practically in column of vessels, but the flying squadron, composed of the Yoshino, Takachiho, Akitsushima and Naniwa, was separated from the main squadron by a distance much greater than that between individual vessels. When the Chinese fleet was first sighted, the vessels of Japan were headed for the center of their antagonist's formation. Admiral Ito changed course so that the head of column was directed towards the right wing of the enemy. The speed of the flying squadron was increased to 10 knots, and when they opened fire the guns were apparently concentrated on the two vessels on the extreme right wing of the Chinese. These two, the Chao Yung and Yang Wei, were first set on fire, and before very long went down. The Akagi, on account of slow speed, and the Sakyo, being in no sense a man-of-war, had taken positions to the left of the main squadron. The flying squadron after inflicting the injuries to the two Chinese vessels, mentioned before, turned to starboard at a distance of about 1600 meters from the Chinese fleet. This squadron was signaled to join the main squadron and began turning to port behind the other fleet. Before this evolution was completed the Hiyei and Akagi had gotten into difficulties, and Admiral Ito made a second signal for the flying squadron to go to the assistance of the smaller vessels. Apparently the shortest way to reach the scene was by continuing the circle, and this accounts for the two turns made by the flying squadron, the explanation of which we were unable to obtain for some time. There are no other reports of any signals having been made by the Commander-in-Chief to the Japanese fleet during the action. As

*Secretary to Commander-in-Chief, Asiatic Station.

the evolutions were performed in good shape by the flying squadron, it is but fair to suppose that the signals were thoroughly understood. The main Japanese squadron advanced to the attack, and the Chinese fleet turned so that their vessels were nearly bows on. Firing at this time became general, the Chinese fire being more rapid (with the large caliber guns), and at the same time very wild. The Hiyei being unable to maintain the speed indicated (10 knots) fell behind the main squadron, and as the latter turned to starboard behind the Chinese fleet, the Hiyei was closed upon by the Chinese vessels. At a distance of about 700 meters the Ting Yuen and Chen Yuen failed to inflict serious damage upon the Hiyei; the latter vessel was set on fire and hauled out of the action. The Chinese had lost all formation as regards distances between ships, and the captain of the Hiyei, fearing to be rammed by one of the battleships if he continued to follow the main squadron, boldly steered his vessel between the two large ships; it was a nervy piece of work, but most successfully executed, and probably saved the ship from utter destruction. The Hiyei subsequently joined the main squadron.

The Akagi also was unable to keep up with the main squadron, and found herself the object of attack from the left wing of the Chinese fleet. The little gunboat was well fought, and finally succeeded in getting away, though roughly handled. The captain was killed on the bridge: a 15-cm. shell struck the pedestal of the bridge gun, glanced and brought up on an iron brace; the shell broke (did not explode) and a fragment killed the captain. The executive officer was shortly afterwards wounded on the bridge, and his place was taken by the navigator, who kept command until the wounds of the executive were dressed, when the latter again assumed charge. The mainmast was shot away, but no one was injured by the fall, for the only top gun that was manned was in the foretop. The maintop was not occupied when the mast fell. On the Akagi, 11 were killed, including the commanding officer, and 17 wounded. In addition to the loss of the mainmast, there were two 15-cm. shells passed through the ship above water, a 3-pdr. shell went through the shield of the stern gun, the top and bridge guns were disabled. It seems a miracle that this small vessel was not blown off the face of the waters. Considering the number and size of the Chinese ships, the short range, and the length of time under fire, the damage done the Akagi was comparatively slight. The accuracy of the Chinese fire in this case is not apparent; it is stated that the sight-bars were never changed after being set for the first range. The main squadron was now circling the Chinese fleet and was joined by the flying squadron, the Yoshino and Matsushima approaching bows on so that the Chinese fleet was surrounded. The Japanese apparently devoted their fire to the battleships, encircling the fleet and increasing the diameters of the circles as they neared the armored vessels, and decreasing the circles as they left them. The Chinese were huddled in the vortex of this fire; stunned

by the volume of projectiles poured upon them, they were without instructions and were out-fought. The Chinese commanders of the smaller vessels sought safety in flight. Sullenly the two battleships held their ground, but their case, under the existing conditions, was hopeless. The Ting Yuen took fire, but was ably protected by her sister ship, the Chen Yuen. The handling of this last named vessel has been complimented in more than one report from the Japanese. Incidentally, it may be remarked that the only American in the fight was on the Chen Yuen; his rank was that of commander, and his duties were to advise the Chinese commanding officer. This American was graduated from the United States Naval Academy.* The Tsi Yuen, Lai Yuen and King Yuen were in active retreat, and in pursuit of these went the flying squadron. The Lai Yuen caught fire, and the Yoshino and Takachiho followed the fleeing King Yuen. Here we find a discrepancy in regard to the fate of this vessel, or rather the cause of her sinking. The first Japanese reports called attention to the fact that this belted cruiser caught fire and went down, being injured by the 15-cm. Q. F. guns of the Yoshino, fired at a distance of 1800 meters. Officers of the Yoshino have made the same statement, and will show, with pride, the gun that they claim did the work. From another officer that was temporarily on board the Yoshino, it was learned that the vessels had approached to within about 800 meters when the Yoshino was preparing to discharge a torpedo. Before the torpedo could be fired the King Yuen listed to starboard, two fires broke out, the stern became submerged, and after a violent explosion on board, probably the bursting of the boilers, the ill-fated vessel disappeared. As the Takachiho was firing at the same time, it seems more probable that the 10-inch guns of this vessel inflicted the mortal wounds. The Japanese still kept up their fire on the two iron-clads, while the latter were slowly making their way in the direction of Port Arthur. The fight ceased before sundown; pursuit not being kept up by the Japanese ships. The remnant of the Chinese fleet succeeded in reaching Port Arthur.

Three torpedoes were fired during the action, and all from the largest of the Chinese torpedo-boats. This boat, with the lieutenant in command, was fallen in with on the first visit of the Baltimore to Port Arthur, before its capture by the Japanese. The lieutenant in command had been ten years in the United States, principally at New Haven, his English was without a flaw, and consequently his narrative was clearly understood. The sea was smooth, not rough as quoted by Mr. Marble, and the conditions were good for torpedo work. The Sakyo after being roughly handled, steam steering gear disabled, had connected hand gear, and at top speed was getting away from close quarters; the Chinese torpedo-boat was speeding in the opposite direction, and under these conditions the vessels approached. Each manœuvred to keep end on; the Sakyo used the machine guns, and the torpedo-boat discharged from the bow first one

* Commander P. N. McGiffin, I. C. N.

and then a second torpedo; both missed. At a distance of 30 meters the third torpedo was launched from turn-table on deck, broadside, at the Sakyo; the torpedo was set for 4½ meters, the Sakyo drew 18 feet, but the short distance between target and torpedo-boat proved the salvation of the former. Before the torpedo had recovered from the initial dive, it had passed under the Sakyo and broached harmlessly on the other side. In the words of the Chinese lieutenant, "It was a golden opportunity, and I missed." The vessels parted company, neither being the least injured in the encounter. There is every reason for believing that the Chinese lieutenant was perfectly up in his work, he was under fire all the time, and yet handled his boat with coolness; the torpedo simply failed to score.

It has never been understood on the station that the large guns of the Chen Yuen were hurt in the least; the information that they were damaged by the fire of the Japanese is an error I think, for having listened to a partial account of the fight given by the American on board the Chen Yuen, the impression received was to the effect that the guns were as serviceable after the action as before; the proper kind of ammunition in the shape of common shell was lacking on the Chinese battleships, and when the fight ended the supply of such shells as were furnished was very short.

Facts that were well known have been accentuated in this engagement. The Japanese took the risk of piling up rapid-fire ammunition on deck in order that the supply might be ample; a shell from one of the 30.2-cm. guns of the Chen Yuen exploded over this pile on the Matsushima, and in turn caused an explosion of the individual projectiles; eighty persons were killed or wounded, the vessel was set on fire, and the large gun put out of action.

On this vessel two shells, one a 6-pdr., exploded in the cofferdam above water, pieces of the shells being found embedded in the cellulose. No damage resulted from these wounds, and as they were all above water, no data is obtained as to the value of cellulose for obturating purposes. The total killed on the Japanese side has been variously given, probably the number will not exceed 100, of which ten were officers. The damages done to the ships were not great, the Akagi, Hiyei, and Matsushima suffering the most, but even these were not seriously damaged. On the Chinese side we find the Chao Yung sunk, the Yang Wei stranded, Chih Yuen sunk, King Yuen sunk, and the Kwang Chia, while fleeing, struck on a shoal outside Talien Wan, and was destroyed. Of the other ships none were badly injured except by fire; hulls and motive power did not suffer, but superstructures and upper decks were simply wrecked by the rapid-fire guns of the Japanese. The Chen Yuen was on fire several times. All the Chinese vessels that were sunk had taken fire. About 600 went down on the Chinese ships, while 100 in addition were either killed or

wounded on the Chinese side. To prevent injury by splinters all the boats from the Chinese ships had been left at Port Arthur, one boat being the allowance for each vessel. The Japanese covered their boats with canvas well wrapped in. On the Chen Yuen, the hose had been led out and water was circulating through them, this being done to prevent unnecessary orders to the engine room in regard to pumps.

The Japanese fleet was officered and manned entirely by natives; their ships individually and collectively were well handled and fought; while the usual dash and nerve, so characteristic of the Japanese nation, was apparent everywhere. From seven to nine foreign officers of military education were on board the vessels that composed the Chinese fleet. These officers were of German, American and English nationalities. Apathetically the Chinese let fires burn that could easily have been put out in the first instance with but little damage. The shells in many instances were improperly fuzed. A naval fight lasting five or more hours took place, with a smooth sea, between two fleets equipped with the most modern appliances of destructive warfare. For the sake of comparison alone it is to be regretted that the fleets were not equipped with men of like characteristics. The result, if such conditions had obtained, would be merely hypothetical. The Japanese not only have learned well the lesson of civilization, but also have gone beyond and have become masters in the art of handling and fighting ships. Their bravery was never a subject for doubt. In this fight we find skill, nerve and ability, with the faster but weaker ships, pitted against the more powerful instruments in the hands of ignorant, apathetic and not over-brave workmen. The question of tactics does not require much discussion. With the Chinese there were none. Admiral Ito started well with his column of vessels; he cornered his quarry and nothing was clearer than that by encircling them he could inflict the death blow. Human beings could not exist in the terrific storm of projectiles that riddled the superstructure of the Ting Yuen and Chen Yuen; no signal halliards remained with which to signal, consequently each individual Chinese captain was left to shift for himself; they displayed greater ability in getting out of action, than in encountering their opponents. The ram was not brought into play, for the faster Japanese ships gave the Chinese no chance for this work; and naturally while the guns were doing such good work, it would have been folly to have rammed with the lighter vessels. The actual resistance of armor was not demonstrated by the Yalu river fight, for the Japanese hardly approached the battleship closer than 3000 meters, and at this distance the 14-inch armor of the Chinese was impregnable. The moral effect of the battleship was beyond question, for these two representatives of that class of vessel stood off the Japanese fleet. The battle was not won so long as they were able to hold their own; had the range been less the story might have been different. The Chinese were confused by the volume of projectiles poured upon the battleships

and withdrew. These two vessels were able to continue the action, and with well disciplined crews, properly officered, would have done so. The danger from fire impresses one with the belief that wood work should be reduced to a minimum; though fires were frequent, the reports were perhaps much exaggerated. The Chinese were confident of success and underrated their opponents. Whether these impressions were fostered by their foreign instructors is not known. The meeting of the two fleets was accidental; for had Admiral Ito known of the vicinity of the Chinese he never would have sent his torpedo boats up the Taitong river. From reliable sources it is learned that if Admiral Ting had known that the Japanese fleet was in the vicinity there would have been no battle. Admiral Ting was caught in a trap, and being unable to escape, accepted the alternative and fought with disastrous results.

Assistant Constructor Y. WADAGAKI, I. J. N.:*—The subject of the paper is a most important one, and one to which a great many people have given their attention. While I do not feel myself competent to express any opinion on the subject, I hope it may be of some use to corroborate the truth of what the writer says, and to call attention to some slight misunderstanding which he seems to entertain. After carefully looking through the paper, one cannot but admire the intellectual ability of the writer who has succeeded in the difficult task of showing the real character of this great naval battle from utterly contradictory reports of various newspapers. The writer is quite right in stating that the battle was fought in the open sea, and not, as is often reported by news correspondents, at the mouth of the Yalu river. True, the Chinese had previously been engaged in convoying the transports of troops. So had been the Japanese. But, at the time of the encounter, neither party had encumbrance of any sort. In fact, the fighting commenced on equal footing, so far as the relative positions of the two opposing fleets were concerned.

The intention of the Chinese admiral seems to have been to get his vessels arranged in line abreast, as they had their guns more strongly developed at the bow than on the broadsides. Admiral Ito's masterly plan of circling round the enemy's fleet and concentrating all his available forces on its weak point from front and rear proved most successful. Due credit must be accorded to the captain of the Hiyei, who, seeing that his ship could not steam fast enough to keep up her position with the rest of the column, boldly broke through the Chinese line and was thus able to destroy its formation. The little Akagi also did good work. Indeed, it is not too much to say that the ability of the admiral, the patriotic devotion of the officers and men, and their training and discipline did as much to decide the fate of the battle as the quality and strength of the vessels themselves.

*Navy Yard, Yokosuka, Japan.

Asking the reason why the Japanese did not continue the battle and push close after the Chinese to the bitter end, the writer of the paper expresses his opinion that Admiral Ito's apprehension of the Chinese torpedo-boats was not justified by the experience he had had of them that day. On this point I am rather inclined to think otherwise. What a torpedo-boat fails to do in the broad daylight she may accomplish with great success under cover of darkness.

Therefore, the Japanese admiral was perfectly right in not risking his ships in an uncertain attempt to complete the victory he had already gained for all practical purposes. He was warranted by the circumstances of that time to preserve his fleet intact in order to be able to proceed at any moment to execute much greater works, if called upon. With reference to the writer's suggestion that Admiral Ito might have done better if he had blockaded the Gulf of Pe-Chi-Li, etc., instead of guarding the coast of Corea, I will only ask him to remember the relative strength of the two contending navies. A fleet that undertakes to blockade the outlet of the enemy must have by far a superior strength. But such had not been the case with the Japanese Navy at the outset of the contest.

As regards the proposed change in the material for warship construction, although it is certain that most of the injuries received by the ships engaged resulted from conflagations, the idea of building the ships entirely of incombustible materials hardly looks practicable. Even if this were possible, what are we to do with the coal carried above the protective deck, which when set on fire would make the whole ship quite uninhabitable? It is therefore most desirable that every vessel of war should be provided with a fire main system arranged in as complete a manner as possible.

Lieutenant WILLIAM P. WHITE, U. S. N.:*—In a pamphlet entitled "The Naval Battle of Haiyang," compiled from official and other sources by Jukichi Inouye, appear reproductions of photographs taken on board the Saikyo Maru as she was withdrawing from action, about 3 P. M. In these the sea appears smooth, the trend of the smoke from different vessels indicating a breeze not stronger than moderate—ideal weather for target practice.

On inspection, Plate II seems to have been taken at the beginning of the fight, Plate III shortly after; still later the plate entitled "The Burning of the Chao Yung." In II, though the plate is not very sharp, the flying squadron is seen a thousand yards at least in advance of the main squadron, the Yoshino leading, Akitsushima third, Naniwa and Takachiho second and last—the vessels in pairs. The main squadron, Matsushima leading, Chiyoda second, Itsukushima and Hashidate third and fourth. Unmistakable are the three sister so-called coast defense vessels, the Matsushima having a high forecastle and her 32-cm. Canet gun on the main deck aft, while the other two have the gun forward and superstructure aft. The

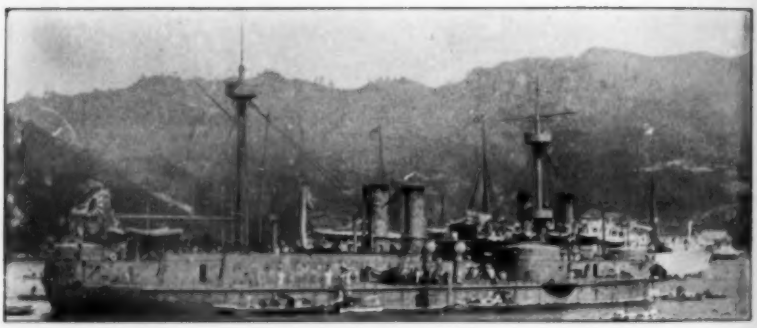
* U. S. S. Charleston, Asiatic Station.

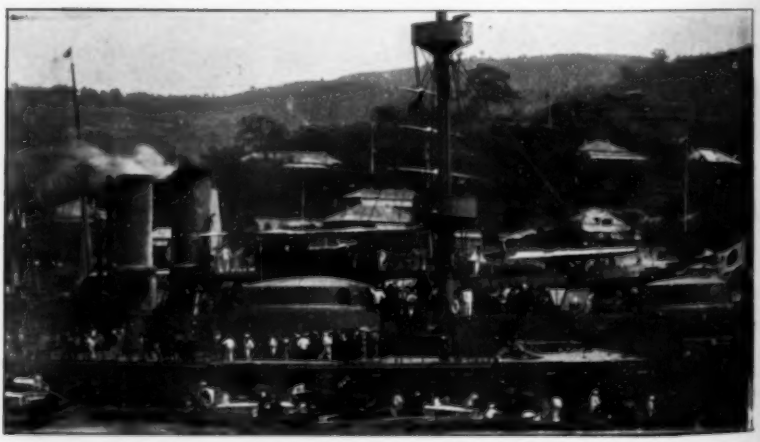
Chinese fleet may be seen in the distance steaming almost bows on and that distance is very considerable. Owing to the arrangement of the Matsushima's battery, the line of battle must be approached at an oblique, this allowing the fleet attacking to maintain the distance as it could with its greater speed, without appearing to run away. The Japanese are said to have commenced the action at 3000 metres, and though decreasing it in regard to smaller Chinese vessels they seem to have maintained it in fighting the battleships.

The reason for attacking the right wing is evident, since the Chinese base lay in that direction; but apart from that, the arrangement of the battery of the Ting and Chen Yuen diagonally from starboard to port, if attacked on that flank, would strike the weakest point of these battleships.

The tactics of the Japanese fleet was then to clip the wing of the Chinese fleet, keep away from the battleships as much as possible and destroy him in detail. Inouye says the flying squadron changed course to port 16 points, and if they turned again 16 points to port they would still be able to bring their starboard batteries to bear on the Chinese fleet, and have it between two fires should the admiral see fit to take his squadron around the right flank of the enemy. This method of moving in a circle was a usual one with the Japanese in maintaining position, and it would have the advantage in this case of giving the speedy flying squadron an opportunity to succor the weaker slower vessels of the column, permitting the admiral, unhampered, to change the direction of the attack. The Matsushima, though badly punished, remained as flagship until after the battle was finished, so Inouye says.

The experience of the Chinese in a former skirmish with Japanese vessels led them to strip their ships, leaving but one boat on board, clearing away all boat davits, etc. But there seems to have been no organized fire brigade, and the disastrous fires which occurred on board their ships should properly have been controlled. In the case of the Ting Yuen a slight fire that might have proved fatal to the ship was put out by the exertions of a European. At Wei-hai-wei, we saw both battleships and there were no evidences then of any considerable fire, though the wooden sheathing, inside the superstructure, was cut up by the projectiles that had passed through it, the shot holes through the skin having been patched. These shot holes appeared to have been made by the smaller rapid-fire guns, and nowhere did there appear marks that might have been made by a 32-cm. projectile, although three of these great guns had been brought to bear on them. The hood of the starboard pair of barbette guns was pierced, but the guns themselves were uninjured, and there appeared nothing that should have affected the port guns. The 6-in. gun in the hood on the bow of the Chen Yuen was disabled. But the damage to both the battleships was immaterial. They were running short of ammunition, and would not have been able to carry on the fight on that account alone.





THE CHEN YUEN AFTER HER CAPTURE. SHOWING OUTLINES OF THE PATCHES PLACED ON THE SIDES.

The Japanese did not strip their ships as the Chinese had done, but their vessels were struck so few times, the precaution seemed hardly necessary; so poor was the quality of Chinese marksmanship that only one of their largest ships had to go to a dock yard for repairs. It may be interesting to know that a table of distances using the Matsushima's mast head angle was found on the Ting Yuen.

As to torpedoes, eight Japanese cruisers with an average of 4 torpedo launching tubes or cars fired not one torpedo; the Chinese fleet was beaten by gun-fire alone. Ten Chinese vessels armed, it is supposed, with torpedoes were equally reticent in making use of them; only the Chen Yuen is said to have fired them from her above-water tubes, as a precaution lest they be struck by gun-fire, and she bears the mark of a projectile close to her starboard forward above-water discharge, very dangerously near.

The presence of torpedo-boats, though they seem not to have been very enterprising, was sufficient to make the Japanese fleet withdraw before dark. It is reported that the electrical connections on board the Japanese fleet were so deranged that they could not use their search lights.

The Chinese fleet was so badly beaten however, that its battleships only went to sea once afterwards, and then to escape from one port to take refuge in another.

It would have been interesting to see what the Japanese torpedo-boats might have done had they been present at Yalu. Their work at Wei-hai-wei leads us to suppose their presence might have made a difference, the Chinese vessels being so poorly supplied with rapid-fire guns of the smaller calibers.

In the Chinese fleet there was not one medical officer; there was one and only one European at Wei-hai-wei.

Lieutenant Sims reports a very complete fire bill on the Chen Yuen, that their hose was led out and pumps running when the ship went into action.

Inouye gives the order of ships: Japanese fleet—Yoshino, Takachiho, Akitsushima, Naniwa, flying squadron; Matsushima, Chiyoda, Itsukushima, Hashidate, Hiyei, Fuso, main squadron, and the Akagi and Saikyo. Chinese fleet in line, right vessel Chao-Yung, then Yang-Wei, Lai-Yuen, King-Yuen, Ting-Yuen, Chen-Yuen, and Ching-Yuen, Kwang-Ping, Tsi-Yuen, Kwang-Chia and Ping-Yuen.

I see from Admiral Ito's remarks published in fragments in the *Japan Mail*, in the battle of the Yalu, that the flying squadron did turn to port; he had *intended* they should go to starboard, doubling on the enemy's right wing. Also he attributes the great loss of some ships with the slight loss of others to the slowness of the Chinese fire, not being able to load fast enough to permit them to fire at *each* vessel as it came up.

The white marks shown in the accompanying photographs are outlines of the *patches* that were placed over the shot holes. The marks in the redoubt are slight indentations which might have been made by 4.7-in. shell.

Ensign MARBLE:—I wish first to express my thanks to the officers who have been kind enough to criticize this essay, especially to Lieutenant Halsey, for the trouble he has taken, profiting by the opportunities he had in serving on the Asiatic station of getting information at first hand, to correct several misstatements of fact and to give a detailed account of the action.

Since the battle of the Yalu was fought now more than a year has passed. Between the writing and publication of this paper more complete and accurate reports have appeared than were then available, the facts are now generally known, every phase of the action has been criticized, and the world has drawn its conclusions. Want of leisure prevents the fulfilment of my original intention to revise the foregoing description and make it as far as now possible a complete history of the battle. Moreover it is unnecessary, since this essay is no longer news. This reply therefore will be limited to correcting misstatements of fact in the original, supplying only the most important omissions, then to modifying or corroborating the conclusions drawn, and finally to answering some opinions expressed in this discussion and in other articles, with which I disagree.

The more important articles on the battle of the Yalu that have come to my notice since this essay was written are the following: The naval battle of Haiyang, compiled from official and other sources by Jukichi Inouye, published in Yokohama,—which contains several photographs taken during the action, the first battle-pictures, it is safe to say, absolutely true to life; Die Seeschlacht von Hai-yun-tau, Der Krieg um Korea bis zur Einnahme von Port Arthur, Folgerungen aus den japanisch-chinesischen Seekämpfen für Kriegsschiffbau und -Armirung, in the *Marine Rundschau* for February, March, and April, 1895,—which last contains very full and detailed tables of the injuries received by the several ships; several articles in the *Revista general de marina*, the *Rivista marittima*, the *Revue maritime et coloniale*, the *Marine française*, the *Yacht*, the *Army and Navy Gazette*, and other papers; the Naval War between China and Japan, by W. Laird Clowes, and Lessons from the War in the East, anonymous, in Brassey's *Naval Annual* for 1895; the report of Herr von Hanneken to Li-Hung-Chang; and last in time, but first in importance as the testimony of a responsible actor in the fight, the article by Commander McGiffin in the *Century* for August, with the review by Captain Mahan.

As for the place where the Chinese fleet was found, it appears that the chart published by the Intelligence Office, from which the one here given was copied, is inaccurate. The island of Talu is off the mouth of the Yalu river. The Chinese fleet was lying to the eastward of the island outside the bar, while the transports and several small craft had gone fifteen miles up the river.* The smoke of the Japanese fleet was sighted about 10

*See Commander McGiffin's plan in the *Century*. The Japanese are said to have possessed accurate charts from their own surveys of the coast made two or three years before.

o'clock; the Chinese immediately got under way, and their smoke was sighted by the Japanese about 11.30.* The sea was smooth and the breeze light.

A few slight corrections ought to be made in the table of the main batteries of the Chinese ships, which however do not materially alter the comparison. According to Commander McGiffin, the King Yuen and Lai Yuen had each two 6″ guns instead of three, the Ping Yuen's heavy gun was 12.2″ inside of 10.2″, the Kuang Ki had three 6″ and four 5″ guns instead of three 4.7″, and the Kuang Ting's three 4.7″s were rapid-fire guns. There are also some differences in the secondary batteries, but the total number of guns is exactly the same as given in the table—120. Commander McGiffin's table of the armament of the Japanese fleet is inaccurate. He seems to have followed the error in Brassey in regard to the Akitsushima. It may be typographical errors that give the Chiyoda fourteen 4.7″ guns instead of 3 pdrs. (the 5″ should be 4.7″), and the Yoshino eighteen instead of eight 4.7″s. Brassey's *Naval Annual* for 1895, by the way, gives the Akitsushima her proper battery at last, but adopts the spelling *Akitsusu*, which is original at least. With regard to spelling it is worth noting that Commander McGiffin gives *Tsi Yuen*, and pronounces it *Tsee*. *Chih Yuen* is pronounced *Chee*. By the same authority the two smaller gunvessels ought to be *Kwang Ping* and *Kwan Chia*.

The actual speeds of the two fleets can now be stated with great probability of certainty. Commander McGiffin gives that of the Chinese as 6 knots (and estimates the Japanese as double theirs); all the Japanese accounts agree that the speed of their main squadron was 10 knots, and that of the van or flying squadron, at times 14. The speeds given in the tables in Commander McGiffin's article differ very little from the maximum trial speeds hereinbefore given. (The average of the Chinese fleet is six-tenths of a knot less, and that of the Japanese two-tenths more in Commander McGiffin's than in these tables.) But since Commander McGiffin states that the Chinese fleet went into action under forced draft, and that in the early part of the engagement it steamed at about 6 knots, and ascribes great advantage to the Japanese in their superiority of speed, it is fair to assume that the Chinese were doing their best, that as a whole they could not keep up any higher speed. The Japanese fleet, leaving out the Fuso, Hiyei, and Akagi, may perhaps have been able to go faster than it did. The greater superiority of the Japanese van must be borne in mind.

The much-disputed order of the Chinese fleet was in fact an indented line, the flank ships somewhat astern of their proper stations. At the beginning of the action there were ten ships in line; the Ping Yuen and Kuang Ting (Kwang Ping) joined later. The Lai Yuen (in Fig. 1.) ought to be in the right wing of the Chinese fleet next to her sister-ship the King Yuen; and the Kuang Ting (Kwang Ping) also, when she came up, joined

* *Marine Rundschau*, February 1895.

that wing. The left wing therefore had originally fewer ships than the right, and the early flight of the Kuang Ki (Kwan Chia) and Chi (Tsi) Yuen left only one ship, the Chih Yuen, on the port hand of the flagship.

In respect to the circling of the Japanese van after it had passed the Chinese flank, the turn was undoubtedly made to port, and not to starboard as shown in the foregoing figures. My apologies are due to Lieutenant Miyaoka for disputing the accuracy of his description on insufficient grounds. The explanation is suggested by Lieutenant White. It may also be there was an error in translation in the report upon which these figures were based: there is often some confusion between port and starboard. Mr. Clowes' article, quoting another version of this same report, says the van, in going to the rescue of the Akagi and Hiyei, "attacked the enemy on the latter's port side," instead of "with their starboard broadsides." Admiral Ito, in a speech in Tokyo on June 30th last, gave the following account:*

"I ordered the first squadron to attack the right wing of the enemy and then to come in upon his rear, utilizing for this purpose the great speed of the vessels of the first squadron. . . . The enemy . . . concentrated his chief attack upon my principal squadron. I managed to keep as far away from him as possible, with a view to attacking him from both sides—front and rear—when the first squadron had got astern of him. A misunderstanding in the signaling took place at this point, however, and the first squadron turned its course in the opposite direction, and consequently the principal squadron had to change its course also" (to which side is not stated, but presumably to starboard).

It thus appears that Admiral Ito first intended to double the enemy's flank as represented in Fig. 2. In a speech nine months after the battle he says a misunderstanding of signals caused the flying squadron to turn to port. Several Japanese reports, written nearer the time, state, as Lieutenant Halsey says, that the flying squadron at that moment was signaled to rejoin the main squadron; in that case it would have to turn to port. However, the fact is certain. Commander McGiffin in conversation said that the Yoshino began to turn to port almost immediately after passing around the Chinese flank, and after turning sixteen points she was heading in the same direction as the Chinese line, which in the meanwhile was standing on. The whole van division had overtaken and repassed around the Chinese flank, firing their port broadsides, before the main squadron passed around for the first time. The main squadron having passed around, the Chinese right wing was between two fires.

It also appears that the rescue of the Hiyei and Akagi by the flying squadron was not done by Admiral Tsuboi's (not Teuboi) initiative, but in obedience to signal from the Commander-in-Chief. His credit is hardly less for the skill and promptness of the execution. To accomplish it the van squadron made a second complete circle with starboard helm.

* Published in the *Japan Mail*.

The officer who succeeded Admiral Ting when he was wounded, was Commodore Liu Poo Chin, captain of the flagship.* Actually the chief command, in so far as any was exercised during the remainder of the battle, appears to have devolved upon Herr von Hanneken, who was nominally adviser to Admiral Ting, but who, in his report to the Viceroy, speaks of "the two vessels placed under my immediate command—the two armor-clads," and mentions the orders given to the fleet as emanating from himself—using the first person. Commodore Lin (not Liu), who afterward ran the Chen Yuen aground, was nominally in command of that ship at the Yalu. Commander McGiffin was her executive officer, but actually fought the ship.

The report that the Chen Yuen's heavy guns were disabled was an error. One of the turrets was jammed for a time, but the main battery kept on firing as long as ammunition lasted. The forward 6″ gun was disabled by an accident to the breech mechanism.

It was also an error to say that the Kuang Ting (Kwang Ping) fled toward the shore. As shown in Commander McGiffin's diagram, she brought up the rear of the retiring column after the battle was over.

The Chih Yuen was sunk in attempting to ram, overwhelmed by gunfire before she reached her target.

The 12″ shell that struck the Matsushima's turret, the very last one in the Chen Yuen's lockers, exploded a pile of ammunition and disabled her 32-cm. gun, besides killing a large number of men. Admiral Ito, however, did not shift his flag until after the battle.

The latter part of the action divided itself into two separate engagements, the two Chinese battleships on the one hand encircled by the five ships of the Japanese main division, while the flying squadron held in check, pursued, or attacked the scattered ships that had formed the wings of the Chinese battle order.

As to the tactical advantage of superior speed much has been written since this battle. One French writer goes so far as to say, "Speed is the principal arm; a squadron which has not an incontestable superiority should decline to fight,"—omitting to explain how the slower squadron can avoid action.† Even an English writer—the anonymous critic in Brassey's *Naval Annual*, 1895—says, "Too much importance cannot be given to the speed of ships and of fleets as a whole." The question is closely connected with the broader one of types of ships and general naval policy. The specialization of types,—as the French call it—torpedo-boats and coast defense ships,—and the sacrifice of offensive power to speed are parts of a theory which is the modern offspring of the discredited and abandoned gunboat policy of the United States, with its corollary of

* *Marine Rundschau*, February 1895.

† M. d'Arthaud in *La Marine française*, quoted in the *Army and Navy Gazette*, Jan. 5, 1895. See also *La Marine française*, July 25, and Sept. 10, 1895, etc.

dependence upon privateers and commerce-destroyers. Without entering into this discussion let it suffice here to repeat the judgment of Captain Mahan: "Inferiority carried beyond a certain degree becomes impotence; nor will all the commerce-destroyers fancy can picture restore the balance to the nation hopelessly weaker in ships of the line-of-battle." Couple with this the opinion expressed in his review of Commander McGiffin's article, "that a given amount of tonnage in one or in a few big ships possesses a decided advantage over the same, or even a greater amount, divided among several.

Something, however, must be said as to the advantage actually derived from superior speed in the battle of the Yalu. Admiral Ito was enabled by it to keep at a distance; and did so to avoid the Chinese rams, since at long range he could profit more by his superiority in rapid gun-fire than he could have profited at close range by his superior speed in a ramming encounter with an equal number of more heavily armored ships. The Chinese, on the other hand, tried to close, if with any intelligent purpose, not as Herr von Hanneken says to get the full advantage of their heavy guns,—which, other things being equal, would have been more decisive at long range where the enemy's lighter ordnance would have been less effective,—but to ram. This the Japanese superiority in speed, but still more their uniform, close, combined, accurate manœuvring undoubtedly prevented. It is obvious that the manœuvre undertaken by the Japanese van could not have been accomplished without vastly superior speed. But it is equally certain that the tactical advantage gained by it could have been frustrated by the Chinese fleet, notwithstanding its inferior speed, had it possessed any manœuvring capacity whatever. And mark, that in this action the difference was enormous,—at least sixty per cent. (10 to 6 knots) in the main division, and more than one hundred per cent. (14 to 6 knots) in the van—a superiority wholly unlikely ever to exist between two tolerably evenly matched fleets of homogeneous battleships. To say that a fleet superior in ordnance and superior in manœuvring capacity gained great advantage over a disorganized and undisciplined enemy by its immensely superior speed does not prove that superior speed will compensate in fighting—not in running away—for inferiority in armament and drill. Only when other things are equal can the tactical value of speed as such be deduced from the equation. Speed is *not* a weapon, whatever enthusiasts may claim, but only a means of making the best use of all the ship's—or fleet's—weapons. It is like saying that because agility is a good thing for a prize-fighter, and lightness promotes agility, the lighter he is the better. Beyond a certain point lightness weakens the force of his weapons, and so the heavy-weight, slow though he be, can beat the light-weight in the end. A battleship is a compromise of weights. Remember the cost in weight of extreme speed, and the sacrifice of offensive power necessary to attain it. In the light of this experience it may even be ques-

tioned if some of the weight given to speed might not more wisely be taken by larger ammunition supply.

A word more about the tactics of the battle. Admiral Ito's official report distinctly states that his column steered first for the centre of the enemy's line. Herr von Hanneken reports that as soon as the enemy was sighted the Chinese fleet weighed and stood directly toward them.* Therefore the fleets approached on opposite courses. This is confirmed by the fact that the battle was opened by a shot from the Ting Yuen aimed at the Yoshino. Then, after the Japanese van had turned gradually to port and a little before it had begun to circle around the Chinese right, the Chinese fleet changed course two points to starboard, trying to keep bows on, which resulted in an irregular wheel, and huddled together the ships on the right flank, which it will be remembered were behind their stations. At the same time the two ships on the left flank, *which had not been in action at all*, took to flight. This accounts for Commander McGiffin, who viewed the action from the Chen Yuen, and does not mention the change of direction of the Chinese line, saying, "as the Japanese fleet approached it steamed along our front from left to right." Commander McGiffin's plan is evidently not drawn to scale, and is misleading as to the distance between the fleets and the direction of the Japanese approach. If the Japanese column had come originally from so far to the eastward, and steamed so close along the front of the Chinese line, it never could have passed its right flank. The photographs taken from the Saikyo Maru, as Lieutenant White points out, show the Chinese fleet at a great distance, approaching bows on. The one reproduced in the *Century*, taken 36 minutes after the Ting Yuen opened fire,† apparently just as the main squadron was coming into action, shows the Chinese fleet still at very long range. A shell has just struck short (on the other side in the picture) of the Chiyoda, the ship next astern of the Matsushima. This seems to furnish the explanation desired by Captain Mahan, of the "manœuvre of steaming in column across the front of the Chinese line, merely to concentrate fire in the end on the right flank, when the left flank could, apparently, equally well have been attacked without the previous punishment." As the fleets approached, their lines of bearing were perpendicular to each other. The Japanese van, opposite the Chinese centre, had to choose which flank to double, and rightly chose the weaker, the Chinese battleships being somewhat nearer the left. The distance of both, and the change of course necessary, to left or right, would be equal in the two cases. The Japanese van passed diagonally along the front of one wing only of the Chinese line, at very long range, and did not open fire until it was about to turn to starboard around the flank, when the distance was still more than 3000 yards. In doing this, it ran no considerable risk. The Japanese main squadron, separated by

*See also *Marine Rundschau* for February and Mr. Clowes' article in Brassey.

†Commander McGiffin gives the time of the first shot as 20 minutes past 12, not 10 minutes before 1.

some distance from the van, was compelled by the change of direction of the Chinese line to pass more nearly parallel along the front of most of what was left of the enemy's fleet,—for by this time two of the three ships in the left wing had vanished,—but still at long range. When the Hiyei, far astern, came opposite the Chinese battleships, the main squadron *had already passed the right flank*. The danger of presenting the broadside to the oncoming prow of the enemy is only the danger of being rammed. Out of range of the ram, so to speak, there is none. It is apt to be forgotten that in these days of high power and flat trajectory an unarmored ship at least is safer, both with respect to the chance of being hit and to the damage done by hits, broadside on than bows on. Now, even more than a hundred years ago, the worst position an unarmored ship can be in, at ranges where gun-fire alone is to be considered, is where she is liable to be raked. Had the Japanese column attacked the left flank instead of the right, it would have run much greater risk; for the Chinese line would then have changed course, or wheeled, to port, and the whole Japanese fleet would have come into closer range with the battleships. Moreover, the two runaways would doubtless have made even greater haste in their flight, and left the flagship and her mate to bear the brunt of the attack only one ship removed from that flank of the line. As it was, both divisions of the Japanese fleet came first into *close* action, not with the centre, but with the right and weaker flank ot the Chinese line. The range at which the flank was turned was 3000 metres at the beginning of the turn and 1600 at the end. The Japanese opened fire at the first-named distance. If this be greater than naval professional opinion would generally approve, it may be replied that the fire of the Japanese fleet in passing once at that range destroyed two ships outright.

Admiral Ito, in the speech already quoted, gives an interesting account of the previous practice of the fleet, which, as it has not been reprinted in this country, is worth repeating here. Speaking of the time just before the outbreak of hostilities, he says:

"At the same time I felt the weight of my duty was largely added to. I thought it very important at this moment to increase the skill of the squadron in active manœuvres. So we daily practised target firing on the open sea. According to the regulations of the navy only a certain number of shots can be fired from each gun at one drill. I thought the regulation allowance was insufficient for the emergencies of the case, so I applied to the Minister of the Navy for permission to use up the ammunition allowed for practise purposes during the coming year (1895). This was refused and we had therefore to practise for the rest of the time with blank charges. [Possibly this means sub-calibre.] I then equipped the steam launches of the various men-of-war in such a way as to ensure them against severe damage in case of collision, and then divided them into two parties—imaginary squadrons—and appointed the two senior officers of

the squadron as the commander of each party respectively, and with them we practised sham fighting. This form of drill is very apt to become half a pleasure, and as a matter of fact in a very short time every boat in the sham squadrons began to evince an inclination to try the ram, as they were all well protected against damage in case of collision. Seeing this, I called a meeting of the commanders of all the boats and cautioned them against any such child's play, pointing out to them that all the vessels we were commanding were not ironclads and were therefore unsuited for ramming. We then set about training so as to avoid any mistakes of actual collision. I ordered all to drill as if they were engaged in actual combat. After this, the tone of their tactics became greatly improved, and all began to manœuvre carefully with a view to avoiding running into each other. This drill was continued until July 23rd, when we received an order to proceed to Chemulpo and moved accordingly."

Both Commander McGiffin and Herr von Hanneken ascribe as one of the chief causes of the Chinese defeat their deficiency in ammunition supply, resulting from the persistent refusal of the authorities at the Tientsin arsenal to furnish shell, of which they had plenty in store, instead of solid shot. Commander McGiffin openly charges treachery as well as official corruption. This undoubtedly was the chief material cause, but it neglects the personal equation. It is rather unfair in Commander McGiffin to claim that the Japanese had twelve ships against the Chinese eight. If he leaves out the two that ran away and the two disabled at the first blow by the superior tactics of their enemies, and omits to count the Chinese torpedo-boats, he ought also to count out the Hiyei, Akagi, and Saikyo, which were disabled early in the action after bearing an honorable part in it, and the last of which was not a man-of-war at all.

It is a pleasure to read Commander McGiffin's high praise of the bravery and discipline of his well-drilled crew and the Chinese sailors in general. Pity is it the same cannot be said of the captains. He thus describes the behavior of Commodore Lin: *

"Commodore Lin was our captain, but he was not to be seen at Yalu. Clearing for action was more than he could stomach even—the fright of anticipation nearly killed him. . . . I kept on hearing a curious noise going on below me in the conning tower every time there was a lull in the firing, and going down there after a while to fight the ship, I came an awful header over Commodore Lin, lying flat on his stomach, cursing and groveling, and praying to Buddha for all he was worth. He belonged to the Mandarin class, and they are all an effete race of arrant cowards."

Some brave officers there doubtless were, but when three out of twelve captains show the white feather what can the physical bravery of crews avail? Someone—I think it was Napoleon—has said, "an army of donkeys led by a lion is better than an army of lions led by a donkey." All

* In an article in the *Per Mare* quoted by the *Army and Navy Gazette*, August 10, 1895.

praise is due to the foreigners in the Chinese fleet, who, working unsupported against great odds, gave their best service to an ungrateful nation and alone deserve the credit for whatever discipline existed.

Herr von Hanneken thus describes the tactical preparation in the Chinese fleet:*

"On first going on board I endeavored to become acquainted with the conditions under which the squadron was to be manœuvred, and I remarked among other defects that the new code of secret signals was not satisfactory and that it did not respond to all the numerous exigencies of command for a fleet of twelve ships. I saw also that the ships had very different speeds and turning circles, and that in consequence it was difficult for them to execute correctly changes of formation and to keep their places exactly during evolutions. This inconvenience was aggravated by the difficulty of the signals, or the lack of attention that had been paid to understanding them; but as it was necessary always to be ready to go to sea, I resolved not to change them, fearing to embarass yet more the crews who might not have time to familiarize themselves with my new code.

"These reasons decided me not to regard the twelve ships of the squadron as forming a single group, but to consider them as single ships, able to unite in ordinary times under the command of an admiral, but before the enemy during battle to act individually at their own risk and peril. The commanders of vessels received in consequence instructions based upon the following principles:

"1. In action sister-ships, or each pair of ships belonging to a subdivision, shall remain together if possible and mutually support each other in attack and defense.

"2. The fundamental tactics will be always to keep bows on to the enemy.

"3. All the ships shall follow as far as possible the motions of the Admiral."

Was ever defeat more plainly foreordained? The battle was fought by the Chinese literally every ship for herself. The only tactical theory was to keep bows on at all hazards without reference to the movements of the enemy. The only instance of combined movement was the action of the Chen Yuen, which kept her station and distance from the flagship throughout. Commander McGiffin's skill in directing the movements and fire of his ship so as to cover and support the Ting Yuen when in straits won the praise of his enemies and undoubtedly, as he says, "prevented the fleet from suffering annihilation instead of its actual heavy loss."

The manner of Admiral Ito's attack has been likened by Captain Mahan to Rodney's action off the Saints in 1782, and by Captain Taylor to Phormio's victory at Patras four centuries before Christ: a striking instance

*Report to Li-Hung-Chang. See also the *Marine Rundschau*, February 1895, and Mr. Clowes" article in Brassey.

of the permanence of tactical principles in spite of change of weapons. If Admiral Ito's tactics were not perfect, if he used his relatively great speed to undertake manœuvres that would have been impossible against an equally fast fleet, or, as Lieutenant Commander Wainwright suggests, that would have cost him dear against a skilfuller foe, no one will quarrel with him, for rashness even, against such tactical lubbers as the Chinese.

Both Commander McGiffin and Herr von Hanneken state that the battle ended by the withdrawal of the Japanese fleet, the latter adding that the Chinese followed them for more than an hour. The Japanese reports state that the Chinese were the first to withdraw. It is unnecessary to reconcile these statements, which are not more different than the testimonies of two witnesses to the same event often are, since the responsibility for discontinuing the action unquestionably rests with Admiral Ito, who had it in his power to continue, while the Chinese had not. He and Commander McGiffin agree that the two fleets stood on parallel courses until dark. Admiral Ito's stated reason, with all respect to Mr. Wadagaki, still seems trivial. He ought not to have "made a picture to himself" of the possible harm from the Chinese torpedo-boats. They were probably worse scared than he. But,—and herein is his justification—for the reason that Mr. Wadagaki himself gives, that "the victory for all practical purposes was already gained,"—the same broad ground that determined the action of Sir John Jervis in a similar case—"he was warranted by the circumstances of that time" in his decision. And he has been amply justified by the result. After this battle the Japanese command of the sea was unchallenged. As Lieutenant White says, "the Chinese fleet was so badly beaten that its battleships only went to sea once afterwards, and then to escape from one port to take refuge in another." As Commander McGiffin says, "before the battles at the Yalu and Ping Yang the Chinese equaled the Japanese in their eagerness to fight; but as the result of these battles gave increased courage to the one, in like measure it disheartened the other."

I cannot agree with Captain Mahan in describing the victory inconclusive. Even its immediate tactical results, considered simply as a naval engagement, were by no means limited to the insignificant Chinese vessels sunk. The battleships were virtually conquered. Commander McGiffin says: "Had they stayed with us a quarter of an hour more, our guns would have been silent and the ships defenseless." It may almost be said that the surrender was merely postponed from the Yalu to Wei-Hai-Wei; for although the two armorclads fought bravely and stubbornly there, surrounded and attacked by land and sea, they were literally caught in a trap whence there was no escape. From the day of the Yalu they had abandoned their strategic mobility and no longer exercised even the deterrent influence of a "fleet in being." Instead of saying, "the subsequent demoralization of the Chinese left to their enemies the control of

the sea, which was decisive of the war, but which the Yalu fight alone would not have conferred," it seems to me truer to say that the victory of the Yalu was the immediate cause of the demoralization of the Chinese navy, which, like the Spanish after Valentine's day, "could no longer be counted a factor in the political situation."

On the strategic question raised in the discussion I beg to differ with Lieutenant Commander Wainwright. The governing conditions undoubtedly are, as he states them: "Where a whole coast or a great commerce must be protected from a fleet, it is sound strategy to blockade closely that fleet, for there being many weak points, it is impracticable to guard all; but where there is one weak point it can be protected best by holding the force at or near the point." It may be added that when the points of departure of the fleet to be watched are few—or one—the reason is all the stronger for blockading it there. Now in this case it seems to me that Japan in her position in Korea had to fear, not for the safety of her army in Ping Yang only or chiefly, but the landing of Chinese troops anywhere on the peninsula. Like England, she had many points to guard. In Korea, with respect to descents of force from China, her general attitude was for the time defensive. Admiral Ito must—or may—have known of the orders of the Tsung-Li Yamen forbidding Admiral Ting to cruise to the eastward of the line from the Shantung promontory to the month of the Yalu river. So actually he had little to fear for the army in the Ping Yang inlet; and the Chinese transports in fact landed not there but in the Yalu river. If it be replied that this is reasoning from knowledge after the event, then it seems to me that against the moral weakness of the Chinese government Japan was justified in assuming the most aggressive offensive, notwithstanding her supposed inferiority in physical force, which actually, considering the quality of her fleet, was more apparent than real. Control of the sea was all-essential to the safety of the Japanese communications; no time ought to have been lost to win it. Had the Chinese fleet been defeated before the landing of troops at Wiju, some subsequent fighting on the march of the Japanese army would have been saved.

It seems to me, also, that the Japanese fleet was strong enough to blockade the Chinese in Port Arthur or Wei-Hai-Wei. Admiral Ito's force was not limited to the eleven ships present at the Yalu. The "Combined Fleet" was divided into the Principal and four Auxiliary squadrons, of which the Principal and first Auxiliary only were engaged in that battle.* The ships composing the second Auxiliary or Western Sea squadron are not named, but the other two contained eleven or twelve cruisers and gunboats. These vessels were not all very fast or very modern, but they would have sufficed for scouts against the slower Chinese fleet, as well as they did as convoys to their own transports. Some of them were in fact "sent daily on scouting expeditions towards Wei-Hai-Wei and elsewhere."

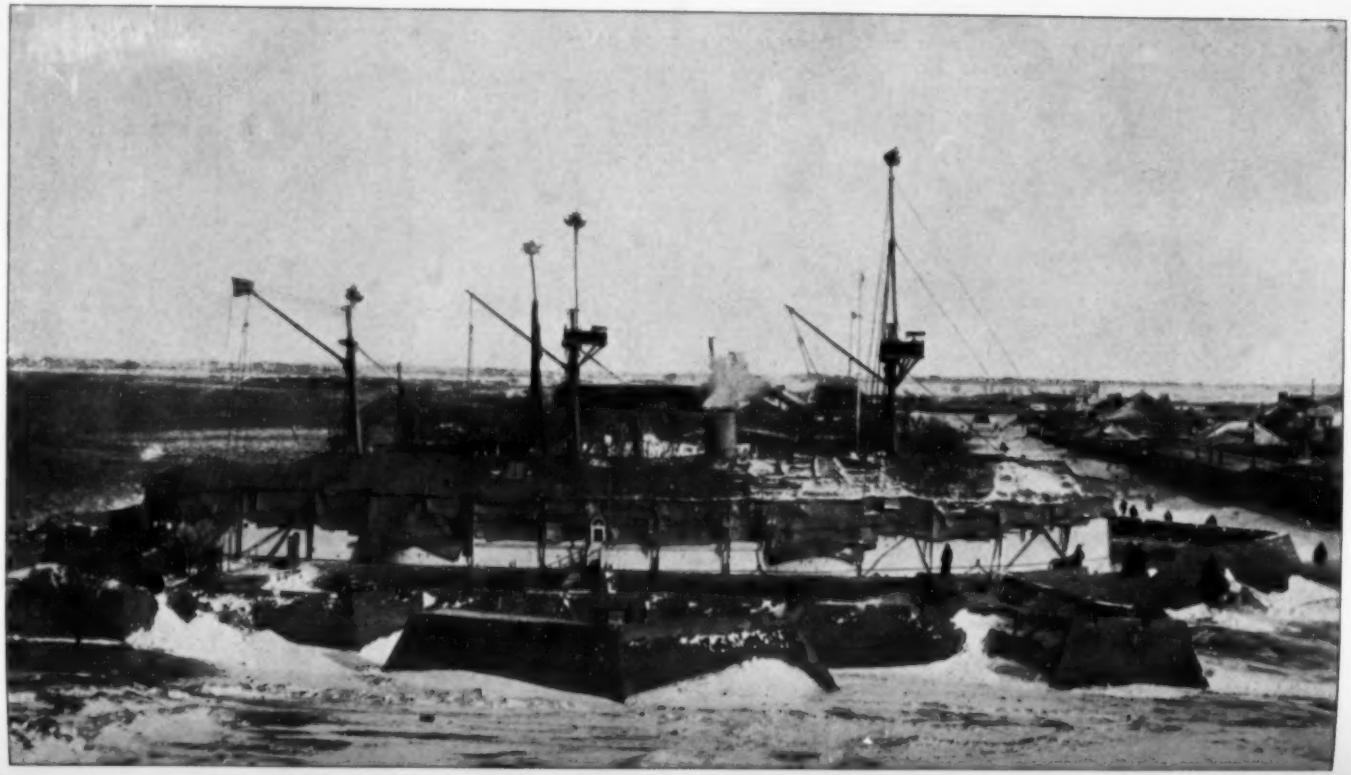
* See Admiral Ito's speech previously quoted, and the pamphlet by Jukichi Inouye.

But Admiral Ito, even if he were not able to press into service more mail steamers like the Saikyo Maru, might at least have kept in constant touch with the Chinese fleet without weakening his "Main" and "Flying" squadrons. It may even be questioned if he would not have been better off in the battle had he left the Hiyei, Akagi, and Saikyo behind. They won the largest share of glory, but in truth were a hindrance rather than a help to the fleet.

But in stating what I believe would have been sounder strategy, I am far from blaming Admiral Ito. He acted under direct orders from headquarters in convoying the armies. The criticism is made wholly upon military grounds, without taking into account the political conditions, which must always influence the action of a commander-in-chief, and with admittedly incomplete knowledge of the general operations of the war. It must be remembered, too, that before the battle of the Yalu all the world thought China possessed the far superior fleet. The Japanese themselves distrusted their navy, ships and men; the administration of the department and the professional ability and even the discipline of the service had been the object of violent condemnation in Parliament and in the press; Parliament had repeatedly refused or only reluctantly granted appropriations for its increase, not on the ground of disagreement with the national naval policy of the Government, but because of the openly charged corruption of the administration and the alleged inefficiency of the service itself.* Admiral Ito's highest honor lies in having demonstrated to the Nation in the crucial proof of war that its fears and its mistrust were groundless.

Happy is it for Japan that in the winter of 1893—in time of peace—when the controversy over the naval appropriations resulted only in repeated upheavals and adjournments of Parliament, the wiser steadfast counsel of the Government prevailed. The lofty patriotism and farsighted policy of the Emperor himself settled the dispute by ordering the contribution of one-tenth of the salaries of all officers of the Government, civil, military and naval, for the term of six years, to the fund for increasing the navy; and himself headed the list by the gift for the same period of one-tenth of the imperial income, amounting to three hundred thousand yen. While we wonder at the authority exercised by a Throne, still hedged around with a majesty half divine whose very reality is strange to our republican eyes, the prophetic words with which the Emperor closed his famous rescript deserve to be had in everlasting remembrance: "A single day's neglect may involve a century's regret."

* See the preface to Jukichi Inouye's pamphlet, and George N. Curzon's "Problems of the Far East," pp. 28-46, etc.



U. S. S. PETREL, CHRISTMAS, 1894.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE PETREL'S INSTALLATION IN MANTCHURIA DURING THE WAR BETWEEN CHINA AND JAPAN.

By LIEUTENANT N. SARGENT, U. S. Navy.

The phenomenon of a modern steel war vessel in commission on a foreign station, and containing a full complement of officers and men, equipment, munitions and stores, remaining for nearly half a year high and dry on shore in a savage country alternately overrun by two Oriental belligerents, and cut off from all connections with the outside world, would under any circumstances be a novel and surprising one; and when, moreover, such an extraordinary situation is the outcome of the natural demands of the service and is due to no fault nor error of judgment, but to a preconceived and carefully worked out plan, it would appear to form a sufficiently unique experience to merit description, and as one of the many anomalous contingencies to which the naval officer is liable, and in which his professional knowledge and ingenuity are drawn upon in entirely new and unexpected directions, a recapitulation of some of its features may not be devoid of interest to members of the Institute.

In October, 1894, the U. S. S. Petrel was in Nagasaki, Japan, undergoing repairs to engines and boilers consequent upon several months' continuous and arduous cruising in Bering Sea, when orders were received to proceed to, and presumably winter at Newchwang, the most northern port of China, for protection of its foreign residents; such protection, always more or less necessary in Chinese treaty ports, being at that time especially so on

U. S. S. PETREL, CHRISTMAS, 1894.

account of an ultra animosity to foreigners, consequent upon the existing hostilities between China and Japan.

These orders were received late in October, and upon such inquiries as could be made concerning the *terra incognita* of Newchwang, a port rarely visited by any of our vessels, several items of information were obtained, which may be recapitulated as pertinent to a comprehensive conception of our subject.

Item A.—That Newchwang was not Newchwang at all, but was called by the Chinese, Yingtze, and sometimes Yenkow, the real city of that euphonious appellation being situated some twenty miles distant, and inland, Yingtze being its port and having appropriated its name.

Item B.—That this so-called Newchwang was a city of Mantchuria, with a population of 70,000 native inhabitants, and a small foreign colony then augmented by some refugee missionaries; that it was to be found at the head of the Gulf of Petchili and fifteen miles above the mouth of the Liáo river, whose navigation was closed from November until April, and that before and after the solid freezing of the river, great floes of ice some thirty inches in thickness, charged up and down its course with every change of tide, and with such force as to render it an impossibility for any vessel to remain at anchor off the town.

Item C.—That a provisional dock could be cut in the soft mud of the river's bank, and that in such a dock the ship might winter and be fully protected from the ice; also, that two precedents for this alternative existed, neither of them very reassuring, but evidencing the possibility of such a plan. The first had been the case of a small British gunboat, H. M. S. Grasshopper, which had been ordered to Newchwang in 1870, but had unfortunately broken her back in entering such a dock, so that she was useless for any further work, and in the spring was sold as old material; the second, that of the U. S. S. Palos, which some ten years later had wintered at Newchwang, and had been docked and undocked successfully.

The latter case was hardly more encouraging than the former, for the contrast between the size of the Petrel with her 890 tons displacement, length of 176* feet and beam of 31 feet, and that of

* Compare this with the length of the old sailing frigates and sloops of war: Constitution, 176 feet; Constellation, 176 feet; Portsmouth, 153 feet; Saratoga, 147 feet.

the Palos, 420 tons, 137 feet length and 26 feet beam, made it very questionable if the experience of the Palos could be taken as a criterion, and if the docking could be accomplished without serious risk to so much larger a vessel.

Item D.—That H. M. S. Firebrand, an antiquated British gunboat of 455 tons, and with a crew of only 45 men, was to keep the Petrel company in her Mantchurian port for the winter.

Item E.—That an inspirating and what was later found to be a quite accurate description of the Petrel's prospective station, could be obtained from the Sailing Directions,* which, on this occasion, seemed to depart from their usual imperturbable enumeration of headlands or dispassionate description of rocks and shoals, and to regard the case as one demanding a certain degree of melancholy eloquence—as may be judged from the following excerpt:

"It is a dreary place. The muddy river winds through a plain of mud without a single natural elevation to break the dismal monotony of the scene, and indeed except for a few weeks during summer, the region in which the port is situated is little more cheerful than an Arctic swamp." To which may be added the pithy dictum of an English traveler, who aptly terms Yingtze "a putrescent cesspool." †

Such scanty information was all that was obtainable, and as there were but a few weeks remaining in which to accomplish the object of our mission there was no time for delay.

The November spring tides happened to come in the second week of the month, and failing to take advantage of these, it was questionable if the dock could be entered at all before navigation closed. An order was consequently telegraphed, and the dock was fairly under way when the Petrel arrived on November 7th.

The first part of the excavation was comparatively easy, the ground being of soft mud, with no rocky formation, but the latter part was hindered by the opening out of springs and quick sands, and by the discovery of certain strata of sand through which the water of the river percolated.

It was specified that the dock should be 220 feet long by 40 feet wide, and that there should be a depth of at least 13 feet 6 inches

* Chinese Sea Directory, Vol. III, p. 655.

† Travels in Mantchu, Tartary, by George Fleming, Esq.

upon the sill, the vessel, after having been lightened and trimmed to an even keel, drawing 12 feet 2 inches both forward and aft; but great difficulty was experienced in getting even 13 feet on the sill owing to an abnormally high tide which had prematurely broken in the as yet uncut gate, and had flooded the dock.

The weather was getting colder each day, the temperature falling below the freezing point at night, and as the Chinese coolies could work upon the sill only at the lowest point of the tide, had no dredger of any kind, but were obliged to dig waist deep in the freezing water, it was doubtful for some time if the requisite depth could be obtained. However, by persistent effort all difficulties were overcome, and on November 12th, a first attempt was made to enter.

The first and even the second and third attempts were unsuccessful, and it was only by a dogged perseverance and by forcing the ship through the mud of the sill with less than 12 feet of water upon it, that she was finally successfully docked. The operation was a hazardous and an extremely difficult one, owing to the following reasons:

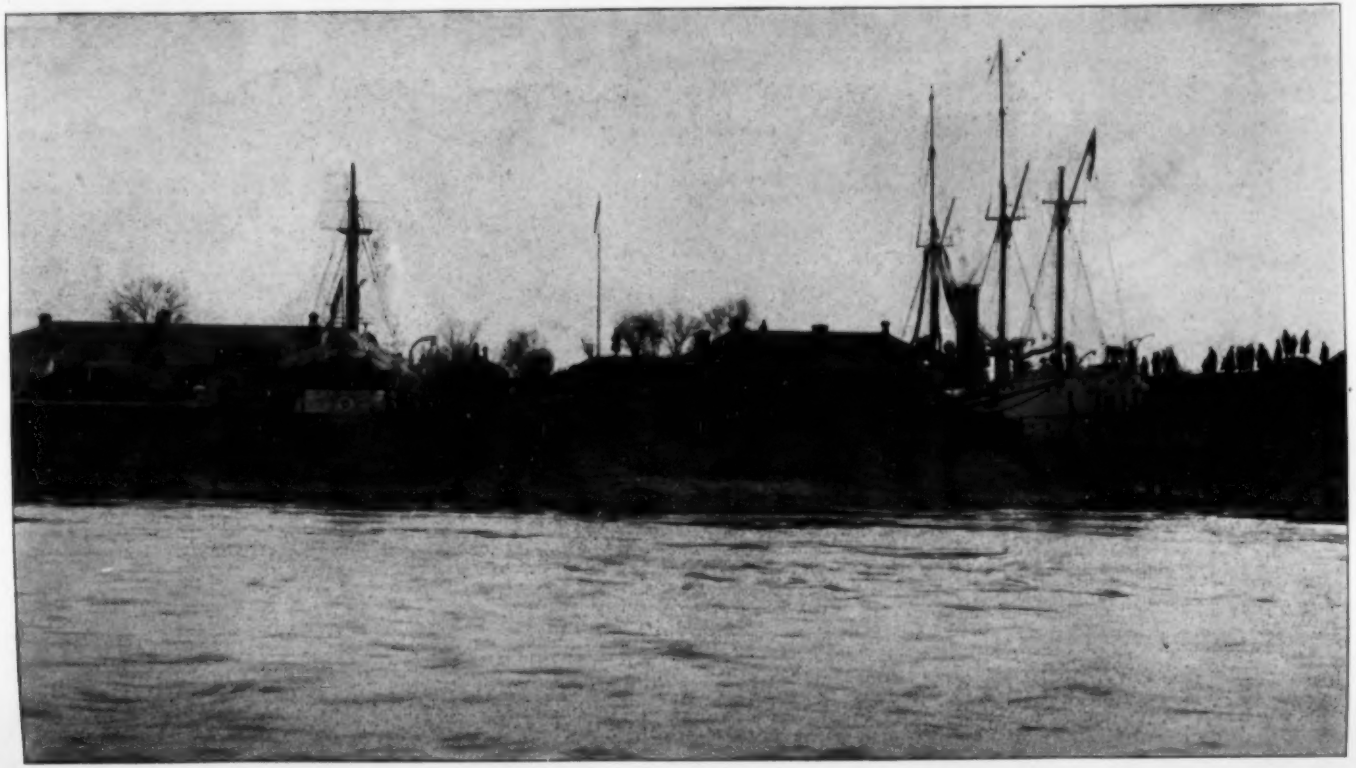
1. The tides in the Liáo, as in many rivers, run with great rapidity, especially at springs.

2. The ebb in shore begins a full hour before the flood ceases running in the center of the stream, thus forming counter currents each of great force, and giving no period of absolute slack water.

3. The best moment to enter the dock was naturally the one when the tide gauge on the sill showed the highest rise of water.

From this it may be understood that when approaching the bank great allowance had to be made for the rapid flood current in the stream, and that on nearing the entrance an almost equally strong ebb was encountered, both currents affecting the vessel at the same time, thus forcing her from her normal position to the bank and bringing her nearly parallel to the shore and obliquely on to the mouth of the dock.

However, by grounding on the corner of the dock, working the engines and helm, backing to drive the water in, and then going ahead full speed to take advantage of the extra depth thus obtained; by heaving with the steam capstan on wire and manilla hawsers bent to anchors which had been buried deep in the ground at the head and on the sides of the dock, and by using others attached



U. S. S. PETREL, TWO DAYS AFTER ENTERING MUD-DOCK.

as guys to the quarters of the ship and manned by hundreds of jabbering coolies on shore, the vessel was at last gotten in. For a week every one had worked day and night, all were fagged out, but the ship was uninjured and the work had been successful.

But what a situation and how hopeless the outlook for the first few days! The natty little vessel whose trim appearance had been the pride of all on board, lying in a hole of slime and water, with decks and sides begrimed with mud, and encompassed with mounds of slippery earth, surmounted by curious groups of Chinese coolies, soldiers and vagabonds of every description, only eager to pilfer or to turn an honest penny by selling liquor to the men; the latrines for officers and men but half completed, the dreary outlook, the town in a state of panic and outrages from Chinese looters expected at any moment and most likely to occur simultaneously with an attack by the Japanese—altogether there have been pleasanter prospects.

But chaos was soon resolved into order, the dock was pumped out and closed, a fortified enclosure sufficient for protection of all the foreign residents was built, the ship stripped and covered in, stoves put up, precautionary measures for fire arranged, water for distilling, lighting and heating provided, military tops constructed, etc, etc.; so that before the last steamer had left and the place had been temporarily cut off from the outside world, the comfort of the crew had been assured and "Fort Petrel" was ready for any emergency.

A short résumé of the work done to accomplish this result will be given under its different appropriate headings.

The Dock.—This was distant some twenty feet from the mean high water mark on the river bank and was 220 feet long by 40 feet wide. As before stated, it was cut into the mud of the bank, this soft earth making an excellent cradle for the ship when the water had been gotten rid of.* The ship was centered by springs and warps, and as the water subsided was plumbed by hawsers to the mast-heads, which held her in a vertical position until all the side shores could be placed. The gate of the dock was then filled in with earth held in place for greater security against leakage and also for protection against the overriding foot ice of the

* On account of the mud and slime in the bottom of the dock it was impossible to place any keel blocks.

shore, by large squares of indigenous rush matting and a crib work of spiles secured by a frapping of old wire hawsers. The dock was then thoroughly roofed over by a bamboo frame work covered in turn with rushes and a layer of mud mortar, thus forming a covering for both warmth and for protection to the metal of the ship's body.

Pits were dug for latrines for officers and men, sufficiently distant from the dock to prevent any transudation into it (*vide* plan), and over these adobe houses were built, giving space for latrines, urinals, washroom for the men with a species of boiler for heating water, and a blacksmith shop. The arrangements of these buildings added greatly to the comfort of the ship's company during the long months of the semi-arctic winter.

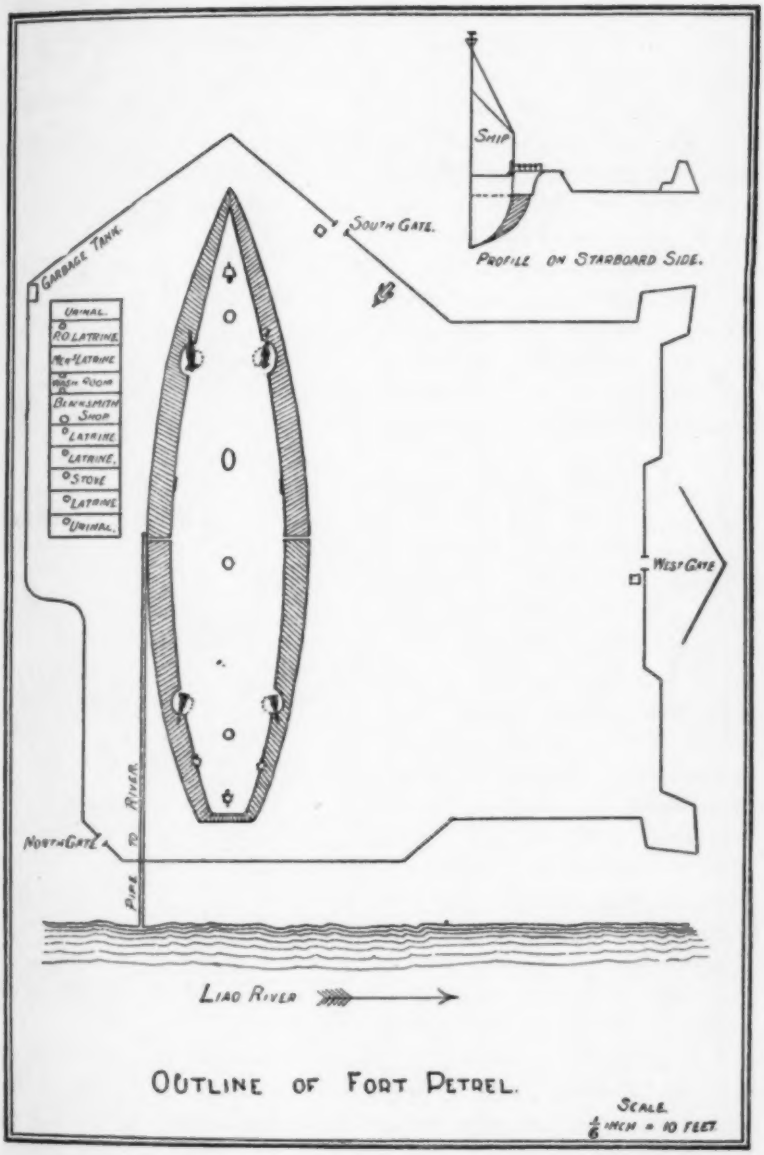
The Fortified Enclosure.—This, under the circumstances, was an absolute necessity not only for the privacy and autonomy of the ship, but also as a place of refuge for the foreign population in case of hostilities or of an uprising on the part of natives.

The excavated earth from the dock formed a ready means of constructing such an enclosure and its lines were at once laid out, special attention being paid to the approaches from which danger was apprehended, and care being taken to preserve a field of fire for the main battery of the ship in case as a last resort this should be needed. The usual profile of fortifications was somewhat modified or inverted to suit the exigencies of the case, the ditch being found next the vessel in the dock itself, and a rampart or species of glacis being left at the edge of the dock for protection against rifle or heavier projectiles.

The parapet of the fortification was eight feet in height, some twelve feet thick at base, and was of the ordinary shape; except that to economize space and so give a greater area for a drill and recreation ground, the banquette slope was more acute than usual and was fitted at intervals with steps for mounting to the banquette tread, while the top of the parapet was crenelated for rifle fire; an emplacement was also provided for a Gatling mounted on its field carriage.

Three openings were left, which were filled in with thick wooden gates, amply secured with heavy iron bolts improvised from broken grate bars and fashioned by the ship's blacksmith.

The main entrance was also defended by an outside curtain or redan. Across the filled-in gate of the dock, a wall eight



OUTLINE OF FORT PETREL.

SCALE.
1/6 INCH = 10 FEET.

feet high of unburnt brick connected the two ends of the earth works.

The whole enclosure when completed gave a continuous line of earthworks about the ship with ample space for the latrines, etc., on the port side, and on the starboard, a parade ground or *terre-plein* 130 feet long by 90 wide. The accompanying outline will show the general disposition of ship and fortification, while the sectional view from the starboard side, gives the profile of ditch, glacis, drill ground and parapet.

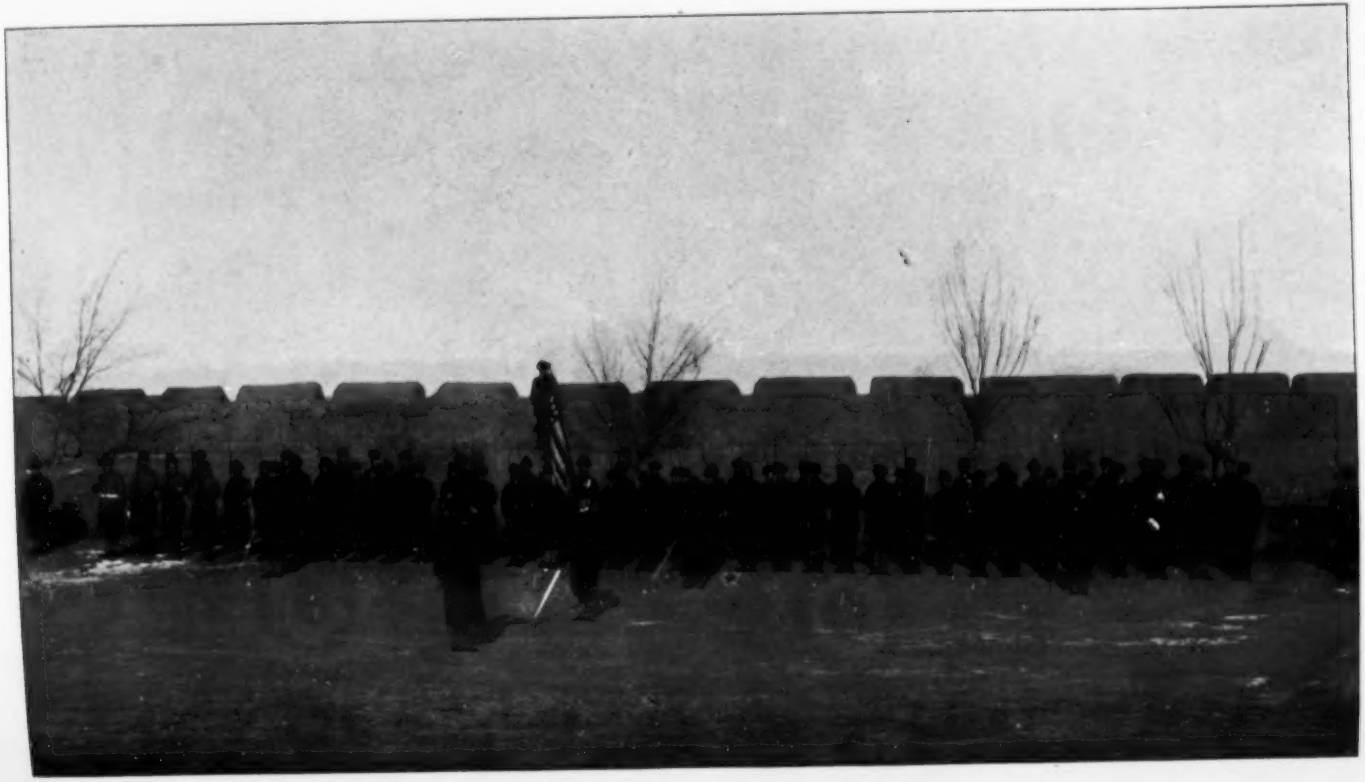
The Ship.—As soon as fully shored and secured, the ship, which is barkentine rigged, was stripped to a girtline on the main and mizzen, but the fore top-mast was left in place for observation purposes, a wise precaution as was proved later, when it became necessary to have a look-out continually aloft to report upon the movements of the Chinese and Japanese troops outside the city walls.

Yards, masts, rigging and stores were stowed in a godown belonging to the American Vice-Consul. The boats were buried on shore in sand, to preserve them from the effects of the extreme dryness of the winter atmosphere and the ship was housed in with a framework of bamboos and poles, fastened like Solomon's temple without sound of hammer, axe or any tool of iron, it being secured together by lashings of coir rope and covered with heavy rush mats, each some twenty feet square, over which in turn a layer of mud was plastered as a protection against fire. This roofing was about twenty feet high amidships and twelve feet above the deck at the sides, the part from edge of scantling to top of ship's rail being hung with smaller and more closely woven mats, fitted with brailing lines in the wake of the guns, so as to roll up to the ridge poles of the scantling when the guns were manned.

A similar arrangement was made at the search light position.

Brows for either gangway and doors, closing the entrances in order to keep out the cold air, were also constructed.

For greater command of the approaches to the ship it was deemed necessary to have some machine guns aloft, and as the vessel was not furnished with military tops, these were made of heavy timbers bolted to the trestle-trees and shored to chocks butting on the futtock bands. An ingenious crinoline mount was



INTERIOR OF FORTIFIED ENCLOSURE.

improvised by the Chief Engineer from some bar iron with an old valve as pivot socket, and a .37-mm. Hotchkiss revolving cannon was mounted in the fore, and a 45-caliber Gatling in the main top.

The other rapid-fire and machine guns could also be efficiently used from their ordinary positions on the forecastle, poop and rail, while, as before mentioned, in case of urgent necessity the main battery could be brought into play. More attention was paid to the starboard than to the port-side, because of the position of the Firebrand on the port beam, and also because the Chinese quarter of the town was situated on the starboard side of the ship.

Strategic Dispositions.—The distances of different salient points of the foreign concession were measured for lines of fire, day and night danger signals for warning the foreign residents determined, and a division of labor for rescue parties from the Petrel and Firebrand in case of emergency agreed upon, the Petrel as the larger vessel taking the lion's share of the work.

Domestic Economy.—The questions of distilling water, of lighting and heating the ship, and of protection from fire when all was ice and snow, were most important problems which called for an early solution.

Before leaving Nagasaki, 250 tons of coal were ordered from Shanghai, and 180 feet of 2½-inch iron piping were obtained and shipped to Newchwang.

With this piping a connection was made with the river, though on account of the low temperature during the winter, the pipes could not be used for ordinary purposes, but were reserved for case of fire.

Water for distilling was carried each day by coolies hired for the purpose, this being an absolute necessity on account of the pernicious character of the local water, so that for the whole term of the vessel's stay in dock, there was no lack of good distilled water. The leakage from the river into the dock, which could not be wholly prevented, was also kept down and utilized for the boilers, and was useful in making steam for electric lighting and for the steam heaters. The latter with the extreme degree of cold experienced, were insufficient for heating the ship, so that such stoves as could be purchased were mounted on the spar deck, in the cabin and in the latrines.

With the inflammable nature of the roof and dock covering, special precautions against danger from fire were necessary, and to this end all the after pump system of the ship was kept connected up, the pipes above mentioned were laid to the river, a special fire-bill made out, grapnels were fitted with long lines for tearing down the scantling and mats, life lines were conveniently placed for men stationed to cut open the river ice (which could not be kept constantly clear on account of the continual changing of the foot ice, with the rise and fall of the tides), and extra squads of axe-men, smotherers, etc., were detailed. Fire hand-grenades were also placed in all parts of the ship in addition to those already in position. Two divisions were detailed as bucketmen, and a large wooden tank eight feet long by five wide was constructed and mounted on the spar deck, kept filled with water, which was prevented from congealing by means of an evaporator coil and steam jet.

Hygiene.—The question of personal cleanliness, always of great importance in such a crowded community as that of a ship's company, was made vitally so by the advent of cold weather and by the consequent disinclination of certain slovenly members of the crew to indulge in more than a very superficial scrubbing. The washroom in the outhouses was heated and hot water was always ready in the morning for the general use of the men, and at night for the different divisions of the ship, who in regular turn were obliged to use it for bathing purposes, the petty officers being required to report that all their men had taken a thorough bath. Clothes and hammocks were scrubbed ashore by native laundrymen and bedding was frequently aired; all living spaces, outhouses, etc., were rigorously inspected each day, the sinks treated with a disinfectant every morning and great supervision exercised over all provisions brought on board.

With the many drills and the daily setting up exercise the men were maintained in most excellent physical condition, and even when on some rare occasions the weather was too severe for drilling, the ship's company was taken out for a brisk run of twenty minutes in the frosty atmosphere, returning with ruddy faces and hoary beards, but in a healthy glow whose effects lasted for hours afterwards.

For the comfort of the men fur caps (of the Elsinore pattern,

with large flaps to cover the back of the neck and the ears) and single finger mittens were obtained, while sheep's skin linings to pea-jackets were allowed, sentry boxes provided, etc. In unusually cold or blustering weather the sentries were relieved every hour, and only one case of slight frost-bite occurred. The effect of such attention may be appreciated from mentioning the fact that in a battle between the Japanese and Chinese on February 24th, which took place only ten miles outside the walls of Newchwang, and when the thermometer was ten degrees below zero, fifteen hundred of the former had their feet frost-bitten.

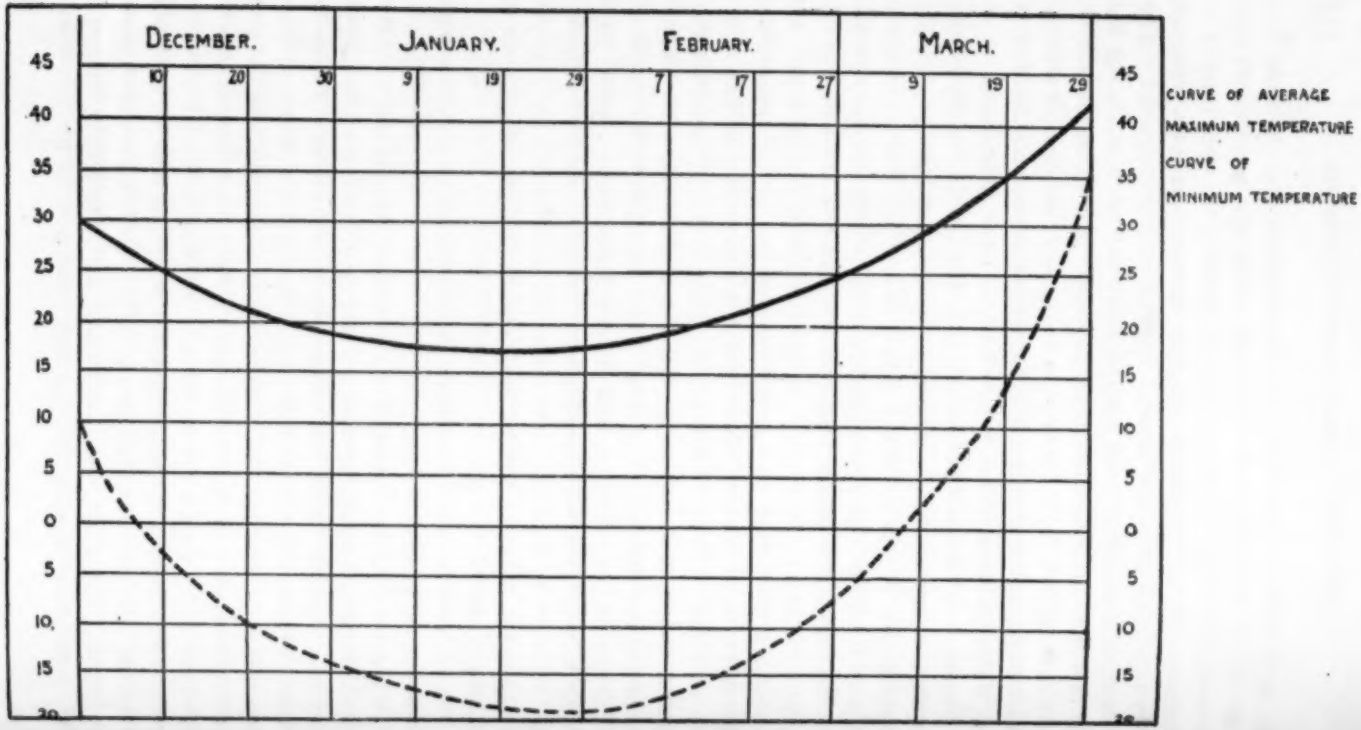
Weather.—Although Newchwang is in the latitude of New York the winters are unusually severe; the temperature is not abnormally low, it rarely falling below minus 20° Fahrenheit, but on account of the high winds or blizzards, which are very prevalent, the cold seems much more intense than it is in reality.

There is comparatively little dampness, but a brilliant, rarefied atmosphere, like that of our Western plains, is the redeeming point of the long winter. Snow falls in November, and at intervals until the middle of March, the ground being continuously covered with it, and not the least of the Petrel's experiences was that of keeping the enclosure clear of this objectionable substance.

Though the cold at times was intense, there were very few days during the whole season when the routine drills could not be carried on. The river was frozen over during the entire winter and served as a passage way for the troops of both belligerents on many different occasions.

The annexed diagram will show the curves of temperature from December 1st to March 31st.

Personnel.—Efficient discipline, constant employment and a fair amount of physical exercise for the people of the ship's company was naturally a subject of earnest consideration. From the moment of entering the dock an organization on a more military basis was a necessity. All men of every department of the ship were apportioned to the battalion; a daily guard detail, with regular morning guard mount at 9 A. M. was formed for outside sentry work, the small marine guard of only ten men being insufficient for this purpose, and being left to their customary duties on board. The rifles were numbered and allotted to the men, each man being responsible for the condition of his piece and



CURVES OF TEMPERATURE.

having it inspected daily at morning quarters, while the policing of the grounds and outhouses was done by extra duty men.

A special routine was made out providing for morning, afternoon and evening drills; and all hands were thoroughly exercised at General and Fire Quarters by day and night, at marching, bayonet exercise, skirmish and street riot drills in good weather, and at other times in revolver practice, aiming, great guns, single sticks, setting up, stations, etc., etc.

At General Quarters all gun divisions were armed as riflemen, and when called away the men of these divisions manned the ramparts while their places at the guns were taken by the powder division.

During the battalion marches all the salient and outlying points for protection were pointed out to the officers and men so that in case of need the rescue duties could be intelligently performed, while simulated attacks on "Fort Petrel"—the men being divided into parties of defense and attack—gave every one an opportunity of judging what surprises might be anticipated and what weak po ints should be particularly guarded. In addition to these exercises al the standing and running rigging was thoroughly examined and refitted, sails and canvas work put in order, signals and other flags made and repaired, machinery overhauled, blocks, boat gear, etc., looked after and in every way occupation furnished for the men and the ship kept in thorough condition. For the amusement of the ship's company parallel and horizontal bars were erected in the enclosure, quoits provided, a tug of war occasionally indulged in and missionaries allowed on board two evenings in the week for a religious and musical symposium. A daily liberty list for the good conduct men was also made out, they being allowed at certain intervals leave until 9 P. M., except on days when the excited feeling was at its height and when there was a possibility of the battalion being called upon, as indeed happened on several occasions.

The men behaved admirably in all respects save one; despite the Utopian theories of certain optimists, who argue that marines may be dispensed with, it was found that the sentries and even the petty officers of the guard could not in many cases be relied upon to prevent the introduction of liquor, and this one subject was the cause of much annoyance and necessitated the most unceasing

vigilance on the part of the officers and the police authorities of the ship.

All those who have passed a few days in dry dock can easily recall the troubles that have invariably arisen, and can therefore comprehend the difficulties attending five months in the same predicament.

Stringent orders were issued to prevent any possible conflict between the men and the natives, and it was greatly to the credit of the former that, although the place was filled with thousands of troops, many of them so called "Hunan Braves" from a province noted for its antipathy to foreigners, no trouble of any kind occurred.

There can be no doubt that the presence and the efficient installation of the "Petrel" resulted in the maintenance of law and order, in place of the riot and outrage which would otherwise have prevailed.

Upon her arrival the city was found to be in a state of panic; the Chinese portion of the town was terrorized by some hordes of Mantchurian desperadoes, who, thrown out of employment by the war, had taken refuge in Newchwang, and had regularly organized themselves for the express purpose of looting the place and of murdering all foreigners; European women and children were leaving, native merchants were closing their shops and fleeing south by every steamer, and all signs pointed to an anarchial state of affairs accentuated by a savage paroxysm of hatred to foreigners.

The moral effect of the Petrel's guns and fortifications soon however gave a different aspect to the situation.

The Taotai (Governor) who was in a lamentable state of trepidation, was encouraged to enforce his authority, and was not only enabled to preserve comparative order, but was emboldened to exclude objectionable refugees (notably the routed army from Port Arthur, which was refused admittance) and to repress lawlessness by decapitating some dangerous characters who were caught placarding the town with inflammatory proclamations.

Both the Taotai and the foreign consuls and residents on many occasions reiterated their assurances that the fortifications, presence and significant preparations of the Petrel had been of inestimable advantage to property and life.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

PRESSURE OF SMOKELESS POWDER GASES IN THE BORE OF GUNS.

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(*Translated from the Russian by Lieut. John B. Bernadou, U. S. N.*)

1. At the present day smokeless powder is being brought into general use for firing from cannon as well as from small-arms.

Recent experiment shows that for the varieties of smokeless powders tried by us the charges develop greater initial velocities for a given maximum pressure than are developed by charges of saltpetre-sulphur-charcoal powders producing the same maximum pressure.

In consequence of this property of smokeless powders, greater pressures are developed by them in parts of the bore near the muzzle than are produced in those parts by the black and brown powders. As a result of this, two important questions arise: (1) To what extent may smokeless powders be employed for firing from guns of present day types? (2) What should be the construction of guns in the future, so that the full advantages to be derived from the use of smokeless powders may be realized?

With the view of ascertaining the ballistic properties of smokeless powder, and also for obtaining practical data for the solution of the above questions, a series of experiments was undertaken by Colonel Yakeemovitch and myself, under the direction of the Artillery Committee, to determine the distributions of pressures realized from firing charges of smokeless powder from guns of the

following calibres: the light gun (3.42-in. cal.); the 4.2-in. gun; the 6-inch. gun of 190 poods (7600 lbs.) weight; the 9-in. gun; and the 11-inch of 25 and 35 calibres approximately.

2. At present the experiments with the light gun, the 4.2-inch and the 6-inch of 190 poods (7600 lbs.) weight are concluded. Detailed accounts of these firings are given in the appended tables.

For the registration of pressures at various points along the bores of the above mentioned calibres, crusher gauges along the sides of the bore and in the breech block were employed.

In using the crusher gauges preliminary shots were fired for the determination of the corresponding preliminary compressions of the copper disks, which should differ from those corresponding to the pressures that would be received upon the firings by about 100 atmospheres.

In conducting the subsequent series of shots (in fives), to be utilized in determining the mean magnitudes of the pressures at different points along the bore, each disk was thus compressed by a second pressure, approximately 100 atmospheres different from the first; and from the result of measurement of its height its special coefficient was calculated.

3. Not losing sight of the fact that the pressures measured by the method employed in the experiment do not correspond exactly to the true pressures developed, nevertheless we may observe that there exists a definite relation between the pressures developed at various points along the bore and the distances of these points from the base of the bore, for all varieties of smokeless powders experimented with. I have deduced the equation expressing this relation and I have ascertained, by application of the method of least squares, the coefficients for the same, based upon the results of the firings with the light gun and the 4.2-inch. I was unable to utilize the results from the 6-inch in the formation of equations, for, with the varieties of smokeless powder employed, a fall in pressure was only to be noted for the three gauges placed nearest the muzzle; the remaining gauges registering approximately the same pressure; so that the experimental data were not sufficient to permit the determination of the form of the pressure curve. The obstacle arose from the fact that the gauges were grouped together close to one another on that part of the gun

strengthened by hoops, which part was comparatively short; and there were only two gauges placed along the unsupported portion.

Having developed the pressure curve, I calculated the work of expansion of the powder gases in the gun available for propelling the projectile.

As the law of variation of pressure upon the base of the projectile from the beginning of its motion to the point of maximum pressure in the bore of the gun cannot be ascertained from experiment with the aid of side crusher gauges, I estimated the pressures for this part of the motion of the shell approximately, defining the curve of pressures by the aid of ordinates calculated by means of the theoretical formulæ of M. Sarrau, Member of the French Academy of Sciences ("Nouvelles Recherches sur les Effets de la Poudre dans les Armes." 1876).*

In almost all cases examined the calculated work falls somewhat under the muzzle energy of the shell. This discrepancy is explained in part by the fact that the muzzle pressures are less reliable, as with disks of the diameters employed, and for pressures of about 300 atmospheres, the disks frequently do not register the residual pressures; or else, the compression is insignificant, as the load approaches closely to the elastic limit of copper, and the disk only compresses under the action of the elastic force. Moreover, the measured pressures may be assumed as less accurate owing to the very brief action of the pressure in these parts upon the copper disks of the gauges.

The equation for the pressure curve developed by me is such as to afford a very simple way of computing pressures at various points of the bore when the pressure at the breech and the initial velocity are known.

For this purpose, having indicated the pressure by means of my equation, we assign to the maximum pressure its place in the bore of the gun (the maximum pressure approximately equals the breech pressure); from the energy of the shell at the muzzle we determine the coefficients of the equation; and we then calculate the pressure at various points along the bore.

The point of the bore for which the pressure reaches a maximum may be approximately determined from the results of the firings with the light gun, the 4.2-inch and the 6-inch.

* See Proceedings U. S. Naval Institute, Vol. X, No. 1, 1884, Whole No. 28, for an English translation of Sarrau's Researches on Powder.—ED.

It is not to be expected that the pressures calculated by the proposed method for various points along the bore represent the true pressures; they are only approximate and serve for estimating resistances of guns designed in the future, for various points along their lengths.

Besides deducing the equations of the curve of pressures, I have discussed other points relating to interior ballistics in my work: namely, I have deduced formulæ for determining the rate of motion of the projectile at various points along the bore, the corresponding times elapsing from the origin of motion, and the pressure of the driving edge of the rifling upon the rotating band of the projectile; besides which I indicate a way of determining the angle of parabolic rifling at its origin, so as to diminish as far as possible the pressure upon the rotating band.

In concluding my work I have, by employing the experimental results and formulæ of Sarrau, given in the memoir above referred to, determined the force of the powder f, and the fractions of the charge burned in various sections of the bore; and finally, I have deduced empirical monomial formulæ for determining initial velocities and breech pressures, using smokeless powders. These formulæ differ from those deduced by Sarrau in the signification of certain exponents of terms expressing the weight of projectile, weight of charge and density of loading.

§ I.

Equations of Pressure.

4. In order to ascertain the pressure of the gases accelerating the projectile in the bore of the gun, it was necessary to find the law of combustion of a charge of smokeless powder.

As this law is unknown, we deduce an empirical equation for the pressure, founded upon the data obtained from firings of the light gun and the 4.2-inch, and based upon the following considerations.

If the bore of the gun were sufficiently long to permit of the whole charge of smokeless powder being consumed, and if subsequently the powder gases expanded according to the adiabatic law; that is, so that they neither lost heat nor received heat from

without,* then the pressures would vary in inverse ratio to the volume of the bore raised to the power 1.41.

As experiments demonstrate that charges of smokeless powders of the kinds experimented with by us continue to burn beyond the point for which the pressure reaches a maximum; and that beyond this point a gradual fall of pressures to the muzzle is to be observed, the pressure cannot be represented by an empirical monomial formula as may be done in the case of saltpetre-sulphur-charcoal powders.

To determine the pressure of smokeless powder gases at various points of the bore, we employ a formula made up of two factors, one of which has the form $\frac{1}{x^{1.4}}$, while the other is an infinite series in ascending inverted powers of x.

Accordingly we have,

$$P = \frac{a}{x^{1.4}}\left[1 + \frac{b}{x} + \frac{c}{x^2} + \ldots\ldots\right], \quad . \quad . \quad . \quad (1)$$

in which x is the distance of any section of the bore from the base of the bore; the volume of the powder chamber being given the reduced length corresponding to the diameter of the bore.

This form of expression fulfils the condition that pressures near the muzzle in long guns vary according to the law of adiabatic expansion as above enunciated.

The coefficients of equation (1) should fulfil one condition; namely, that for $x = x_m$, where x_m corresponds to the point of the bore for which the pressure is a maximum, the derivative of x for the pressure P should equate to zero; that is,

$$(P')_{x=x_m} = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

By formula (1) the pressures developed at sections of the bore in front of the point at which the maximum pressure occurs may be determined. Pressures that are developed between the origin of displacement of the projectile and the point of the bore at which the maximum pressure occurs cannot be determined by crusher gauges ranged along the sides of the bore.

To determine approximately the pressures in these latter portions of the bore we have employed the theoretical formulæ of Sarrau, as explained below in paragraph 6.

* Insignificant losses in heating the walls of the gun, and in certain other ways are disregarded.

Having calculated the coefficients of equation (1) by the method of least squares, from the data obtained from firings of the light gun and the 4.2-inch, we find that to determine pressures within the limits of practical accuracy it is only necessary to preserve three terms of series (1). The differences between observed and calculated magnitudes thus found do not exceed the limits of errors which may occur in the quantities as due to method of measurement employed.

Placing

$$P = \frac{A}{x^{1.4}} + \frac{B}{x^{2.4}} + \frac{C}{x^{3.4}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

differentiating for x and substituting for x, x_m, we obtain,

$$(P')_{x=x_m} = -1.4\frac{A}{x_m^{2.4}} - 2.4\frac{B}{x_m^{3.4}} - 3.4\frac{C}{x_m^{4.4}} = 0,$$

whence,

$$C = -\frac{1.4}{3.4}x_m^2 A - \frac{2.4}{3.4}x_m B, \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and equation (3) takes the form

$$P = \frac{A}{x^{1.4}}\left(1 - \frac{1.4}{3.4}\frac{x_m^2}{x^2}\right) + \frac{B}{x^{2.4}}\left(1 - \frac{2.4}{3.4}\cdot\frac{x_m}{x}\right), \quad . \quad (5)$$

or

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)^{*}, \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where

$$a = A\,;\ b = \frac{B}{A} \text{ and } c = \frac{1.4}{3.4}x_m^2 + \frac{2.4}{3.4}x_m\frac{B}{A}. \quad . \quad . \quad (7)$$

Calculations show that for the varieties of smokeless powders experimented with by us, the coefficient of the last term is subtractive, whence the minus sign is placed before c in (6).

5. Upon the basis of data obtained from firings of the light gun and the 4.2-inch, the coefficients of equation (6) have been calculated by the method of least squares, for all typical † cases

* Pressures developed by saltpetre-sulphur-charcoal powders may be expressed by a similar formula, but the exponent 1.4 in the first factor must be reduced in magnitude to 1.2 or even 1.1.

† Upon firing reduced charges of smokeless powder from the light gun, pressures were evidently not registered with sufficient accuracy by the two

arising from firing charges of smokeless powders, and pressures have been determined by this formula for all points of the bore at which pressure gauges are placed.

The results obtained by experiment and by calculation are arranged in Tables I and II. Pressure curves have been constructed for Okhta smokeless powder tried in the light gun and the 4.2-inch and are shown in Plates I and II in broken lines.

We will illustrate, as an example, the manner of calculating the coefficients of equation (6) from data obtained from firing charges of Okhta smokeless powder (thickness of strip .035-inch) from the 4.2-inch gun employing a projectile of $39\frac{3}{4}$ lbs. weight.

In order to determine x corresponding to any point of the bore, it is necessary first of all to give to the powder chamber its reduced length corresponding to the diameter of the bore.

In the case of the 4.2-inch gun, it is therefore necessary to increase the distance of each point of the bore from the base of the bore by 6.68 inches.

Whence,

$$x_m = \frac{35.68}{4.2}\,;\; x_1 = \frac{40.28}{4.2}\,;\; x_2 = \frac{48.68}{4.2}\,;\; x_3 = \frac{59.88}{4.2}\,;$$

$$x_4 = \frac{68.48}{4.2}\,;\; x_5 = \frac{92.08}{4.2}\,;\; x_6 = \frac{134.08}{4.2}\,.$$

Corresponding to the above written magnitudes of x, we have the following observed pressures (Table II):

For x_m, a pressure of 1693 atmospheres
" x_1, " " 1658 "
" x_2, " " 1490 "
" x_3, " " 1154 "
" x_4, " " 872 "
" x_5, " " 509 "
" x_6, " " 323 "

Substituting these quantities in equation (5), we obtain the equations of condition, which, arranged in relative order of magnitude of coefficients, reduce to the form

gauges placed nearest the muzzle, and there were only three sets of observations left for calculating the coefficients in equation (5). This number was evidently insufficient for determining these coefficients within the limits of precision required.

$$
\left.\begin{aligned}
u + v - 1 &= 0,\\
0.9709u + 0.9521v - 0.9793 &= 0\\
0.8566u + 0.7784v - 0.8800 &= 0\\
0.7031u + 0.5686v - 0.6816 &= 0\\
0.6060u + 0.4494v - 0.5150 &= 0\\
0.4229u + 0.2537v - 0.3006 &= 0\\
0.2563u + 0.1135v - 0.1907 &= 0
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (8)
$$

where

$$u = \frac{A\,[\bar{2}.4687]}{1693} \text{ and } v = \frac{B\,[\bar{3}.2385]}{1693}.$$

The numbers enclosed in the brackets are logarithms.*

Denoting the coefficients of a by u, and the coefficients of v by b, and the indicated magnitudes of the unknown quantities by n, we form the normal equations

$$
\left.\begin{aligned}
(aa)u + (ab)v - (an) &= 0\\
(ab)u + (bb)v - (bn) &= 0
\end{aligned}\right\}, \quad . \quad . \quad . \quad . \quad (9)
$$

where $(aa) = 3.7823$; $(bb) = 3.1150$; $(ab) = 3.3997$;
$(an) = 3.6720$; $(bn) = 3.3342$.

Solving the normal equations, (9), we find

$$v = \frac{(bn\,.\,1)}{(bb\,.\,1)} = 0.56926, \dagger$$

and

$$u = -\frac{(ab)}{(aa)}v + \frac{(an)}{(aa)} = 0.45919.$$

Having calculated

$$A = u\,\frac{1693}{[\bar{2}.4687]} \text{ and } B = v\,\frac{1693}{[\bar{3}.2385]},$$

we assign, by (7), the coefficients in (6),

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right).$$

* When minus signs are written over characteristics, the characteristics are to be taken as negative. Thus, following *our* notation, $\bar{2}.4687$ is to be read 8.4687—10.—J. B. B.

† In substituting the above values in (9) v is found 0.56696, instead of 0.56926, as given in the text. This minor error is here disregarded and the example allowed to stand in its original form.—J. B. B.

For the case under consideration

$$\log a = 4.4220;\ \log b = 1.3235 \text{ and } \log c = 2.1931.$$

Substituting in the first two members of equation (8) the values found for u and v, and multiplying the sum of these terms by 1693, we obtain pressures for points of the bore corresponding to those at which pressure gauges are placed and where the pressures are measured. The calculated pressures are given in Table II, along with those obtained experimentally.

6. It was stated above that we had utilized the theoretical deductions of Sarrau in determining approximately the pressures developed in the bore from the origin of motion to the instant of development of maximum pressure, which occurs for that section of the bore (measured from the base of the bore) for which x has the value x_m. The manner of estimating pressures at these sections, and also the method of calculating initial velocities and times, are explained below, the solutions of these problems being interdependent.

In his memoir "Recherches Théoriques sur les Effets de la Poudre" 1874–1875, Sarrau has deduced the following differential equation of motion of a projectile in the bore of a gun,

$$(u + u_0)\frac{d^2u}{dt^2} + \theta\left(\frac{du}{dt}\right)^2 = f\frac{y}{M}, \quad . \quad . \quad . \quad . \quad (10)$$

where u represents the distance traversed by the projectile from the origin of motion,

M, the mass of the projectile,

f, the force of the powder,

y, the weight of the products of combustion which are generated in the instant of time, t,

$\theta = \frac{n-1}{2}$, and n, the ratio of the specific heat of a gas at constant pressure to the specific heat of the gas at constant volume. For perfect gases $n = 1.4$; whence, $\theta = 0.2$.

$$u_0 = \frac{\tilde{\omega}}{s}\left(\frac{1}{\Delta} - \frac{1}{\delta}\right). \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$\tilde{\omega}$, the weight of the charge,

s, the area of cross section of the bore,

δ, the density of grain or strip of powder,

Δ, the density of loading.

Integrating the above differential equation (10) by approximative methods, Sarrau deduced expressions y_o, $\frac{dy_o}{dz}$, $\frac{d^2y_o}{dz^2}$, corresponding to the different values of z (see p. 87, Nouvelles Recherches sur le Effets de la Poudre dans les Armes, 1876).*

Through the aid of these expressions we may calculate with necessary accuracy the pressure of the gases, P, the velocity of the projectile, v, and the time, t, elapsed from the origin of motion of the projectile.

We have,

$$t = \frac{z}{K^\beta}, \quad \ldots \ldots \ldots \quad (12)$$

$$v = u_o K^\beta \frac{dy_o}{dz},$$

and the pressure $$P = M u_o K^{2\beta} \frac{d^2 y_o}{dz^2}.$$

If we denote by P_m and v_m the pressure and velocity corresponding to the section of the bore at the distance x_m from its base, then

$$P_m = M u_o K^{2\beta} \left(\frac{d^2 y_o}{dz^2}\right)_m,$$

and

$$v_m = u_o K^\beta \left(\frac{dy_o}{dz}\right)_m,$$

whence,

$$M u_o K^{2\beta} = \frac{P_m}{\left(\frac{d^2 y_o}{dz^2}\right)_m},$$

and

$$u_o K^\beta = \frac{v_m}{\left(\frac{dy_o}{dz}\right)_m}; \quad \ldots \ldots \quad (13)$$

therefore,

$$P = P_m \frac{\frac{d^2 y_o}{dz^2}}{\left(\frac{d^2 y_o}{dz^2}\right)_m} = m' P_m, \quad \ldots \ldots \quad (14)$$

* Proceedings of the U. S. Naval Institute, Whole No. 28, page 128. In these expressions z is the time in other units than seconds (see equation (54), page 108) and y_o is travel (defined by equations (64) and (50)).—Ed.

and

$$v = v_m \frac{\frac{dy_o}{dz}}{\left(\frac{dy_o}{dz}\right)_m} = m'' v_m , \quad . \quad . \quad . \quad . \quad . \quad (15)$$

where

$$m' = \frac{\frac{d^2 y_o}{dz^2}}{\left(\frac{d^2 y_o}{dz^2}\right)_m} , \text{ and } m'' = \frac{\frac{dy_o}{dz}}{\left(\frac{dy_o}{dz}\right)_m} .$$

In order to develop a formula serving to determine the time, t, we must find first the quantity K^β from equation (13) and substitute it in (12).

We have,

$$K^\beta = \frac{v_m}{u_o} \frac{1}{\left(\frac{dy_o}{dz}\right)_m} ,$$

and

$$t = \frac{u_o}{v_m} \left(\frac{dy_o}{dz}\right)_m . z .$$

Denoting the path of the shell from its origin of motion to the point corresponding to the maximum pressure of gases in the bore by u_m, we have (p. 55, Nouvelles Recherches) *

$$u_m = (y_o)_m u_o .$$

whence,

$$u_o = \frac{u_m}{(y_o)_m} ,$$

and

$$t = \frac{u_m}{v_m} \frac{\left(\frac{dy_o}{dz}\right)_m}{(y_o)_m} . z = m''' \frac{u_m}{v_m} , \quad . \quad . \quad . \quad . \quad (15)_1$$

where

$$m''' = \frac{\left(\frac{dy}{dz}\right)_m}{(y_o)_m} z .$$

* This is an application of equation (50) in Whole No. 28, Proceedings U. S. N. I. The second member terms of equation 64, except the first, are omitted. (Pages 108 and 109, Proceedings.)—Ed.

Sarrau's tables (p. 91,* Nouvelles Recherches) show that the maximum pressure of the gases in the bore of the gun corresponds to $(y_o)_m = 0.6$. The deduced value of $\frac{d^2y_o}{dz^2}$ given in this table corresponds to magnitudes of y_o, differing by increments of 0.1.

Employing the tables taken from the above mentioned memoir, we calculate the coefficients m', m'' and m''', found in (14), (15) and $(15)_1$, for values of u differing by $\frac{u_m}{6}$.

The logarithms for these coefficients, arranged for convenience in computation, are given in the following table.

u	$\log m'$	$\log m''$	$\log m'''$
$\frac{u_m}{6}$	$\bar{1}.8299$	$\bar{1}.4871$	0.3267
$2\,\frac{u_m}{6}$	$\bar{1}.9295$	$\bar{1}.6953$	0.4011
$3\,\frac{u_m}{6}$	$\bar{1}.9715$	$\bar{1}.8148$	0.4518
$4\,\frac{u_m}{6}$	$\bar{1}.9894$	$\bar{1}.8923$	0.4822
$5\,\frac{u_m}{6}$	$\bar{1}.9938$	$\bar{1}.9354$	0.5102
u_m	0.0000	0.0000	0.5332

In completion of the data coordinated in the above table we may add that for $u = 0$ the coefficients m', m'', and m''' also reduce to zero.

§ II.

Work of Pressure of Powder Gases, Velocities of Projectile and Intervals of Time.

7. The work performed by the powder gases, from that section of the bore at which the pressure reaches a maximum to the muzzle, is determined by the integral

* Proceedings U. S. N. I. Whole No. 28, page 132.—Ed.

$$\int_{x_m}^{X} P dx = a \int_{x_m}^{X} \frac{1}{x^{1.4}} \left(1 + \frac{b}{x} - \frac{c}{x^2}\right) dx,$$

or,

$$\int_{x_m}^{X} P dx = \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2}\right) \right\}_{X}^{x_m}, \quad . \quad (16)$$

in which X represents the full length of the bore.

If P be given in atmospheres and x in calibres, then, in order to express the above integral in standard units of work, it is necessary to multiply it by the quantity $q.2R$, in which $2R$ denotes the calibre expressed in lineal units, and q, the pressure of one atmosphere on the area of the base of projectile and rifling, expressed in units of weight.

To represent the work of the powder gases over the distance u_m, from the origin of motion of the shell to the point of maximum pressure, we must estimate the magnitudes of the pressures in these parts by the method explained in the preceding section. We find in this way seven ordinates for determining the form of the curve of pressures, namely :

For $u = 0$ ..... $P_0 = 0$

" $u = \frac{u_m}{6}$ ..... $P_1 = m'_1 P_m = 0.6759\, P_m$,

" $u = 2\frac{u_m}{6}$ ..... $P_2 = m'_2 P_m = 0.8501\, P_m$,

" $u = 3\frac{u_m}{6}$ ..... $P_3 = m'_3 P_m = 0.9365\, P_m$,

" $u = 4\frac{u_m}{6}$ ..... $P_4 = m'_4 P_m = 0.9759\, P_m$,

" $u = 5\frac{u_m}{6}$ ..... $P_5 = m'_5 P_m = 0.9858\, P_m$,

" $u = u_m$ ..... $P_6 = P_m$.

Applying Simpson's rule of quadrature, we determine the work of pressure of the powder gases,

$$\int_0^{u_m} P dx = \frac{u_m}{6} \cdot \frac{1}{3} \{P_0 + P_6 + 2(P_2 + P_4) + 4(P_1 + P_3 + P_5)\} = 0.8366\, P_m u_m ;$$

whence the work performed by the powder gases over the distance u_m becomes

$$Q = 0.8366 \, . \, q P_m u_m , \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

where u_m is expressed in units of length.

8. By formula (5), pressures such as are measured with the aid of crusher gauges at various points of the bore are determined. Under the assumption that this formula represents a pressure on the base of the projectile during its motion through the bore of the gun, we have that the sum of the works of pressure of the powder gases, as determined by formulæ (16) and (17), will be the work expended in imparting accelerating and rotating impulses to the projectile, and in overcoming the friction of the rotating band against the rifling, neglecting the work spent in overcoming certain resistances, such as the resistance of the air to the motion of the projectile, etc.

Calling p the weight of the projectile, V the initial velocity, and g the acceleration of gravity, we have

$$(1 + \nu) \frac{p V^2}{2g} = \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_{x}^{x_m} q . 2R + Q. \quad (18)$$

where the calibre, $2R$, is expressed in the same lineal units as the velocity V, and q, the pressure of one atmosphere over the base of the projectile and rifling, is expressed in the same units as the weight of the projectile p.

The coefficient

$$\nu = \nu_1 + \nu_2 , \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where the quantity ν_1 depends on the part of the work of pressure expended in imparting rotation to the projectile, while ν_2 represents the portion of the work expended in overcoming friction of the rotating band against the rifling.

9. The quantity ν_1 is determined by the following method: If we denote by A the moment of inertia of the projectile about its axis of configuration and by ω its angular velocity of rotation at the muzzle, there is expended in imparting energy to it an amount of work equal to

$$\frac{\omega^2 A}{2} .$$

For elongated projectiles,

$$A = \mu \frac{p}{g} R^2,$$

where R represents half a calibre. The coefficient $\mu = 0.53$ for cast iron and armor-piercing projectiles of lengths of from 2.5 to 3.5 calibres. For projectiles of length from 3.5 to 4.0 calibres, $\mu = 0.55$; and $\mu = 0.60$ for thin-walled bursting shell.

Remembering that $\omega = \frac{2\pi V}{2\eta R}$, where η is the number of calibres the projectile must travel in order to make one complete turn, we have

$$\frac{\omega^2 A}{2} = \frac{p V^2}{2g} \mu \frac{\pi}{\eta^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

whence the coefficient

$$\nu_1 = \mu \frac{\pi^2}{\eta^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

10. To determine the work expended in overcoming friction of the rotating band upon the rifling, formulæ for the pressure of the driving edge of the rifling against the rotating band of the projectile are required. The method of developing these formulæ is explained below.* Denoting by N the sum of the pressures taken in a direction perpendicular to the radius produced at the centre of the projections, we have the following equations of motion of the shell, in the direction of the axis of the bore and around the axis of configuration of the shell:

$$\frac{p}{g} \frac{d^2x}{dt^2} = qP - N(\sin\theta + f\cos\theta), \quad . \quad . \quad . \quad (22)$$

$$A \frac{d\omega}{dt} = RN(\cos\theta - f\sin\theta), \quad . \quad . \quad . \quad (23)$$

where f is the coefficient of friction, θ the angle between the spiral line of the rifling and the element of the bore, and qP the pressure of the grooves on the base of projectile, expressed in units of weight.

* Formulæ relating to this subject are deduced in the lithographed Course of Interior Ballistics for the Michaelovsk Artillery Academy, by Lieutenant-Colonel Brynk.

When the projectile has passed a certain distance along the bore x, it has rotated through an angle φ, so that $y = R\varphi$, where y is the ordinate corresponding to the abscissa x and described upon the developed surface of the bore.

We have,

$$\frac{d^2y}{dt^2} = R\frac{d^2\varphi}{dt^2} = R\frac{d\omega}{dt},$$

whence,

$$\frac{d\omega}{dt} = \frac{d^2\varphi}{dt^2}.$$

Substituting the latter expression in (23), and putting $A = \mu\frac{p}{g}R^2$, we find,

$$\frac{p}{g}\frac{d^2\varphi}{dt^2} = \frac{N}{\mu R}(\cos\theta - f\sin\theta). \quad . \quad . \quad . \quad (24)$$

11. For rifling of uniform twist, we have

$$y = R\varphi = x\tan\theta,$$

$$\frac{d^2\varphi}{dt^2} = \frac{\tan\theta}{R}\frac{d^2x}{dt^2},$$

and equation (24) becomes

$$\frac{p}{g}\frac{d^2x}{dt^2} = N.\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{\tan\theta}. \quad . \quad . \quad . \quad (25)$$

Equating the second members of the last equation and (22), we have

$$N = qP\frac{\mu\tan\theta\sec\theta}{1 - f\tan\theta + \mu(\tan\theta + f)\tan\theta}. \quad . \quad . \quad (26)$$

As the angle θ and the coefficient f are small, we may neglect $f\tan\theta$ and $\tan^2\theta$ in comparison with unity and putting $\sec\theta = 1$, we obtain the approximate expression

$$N = \mu qP\tan\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

giving the value sought within the limits of requirements of practical accuracy.

12. Assuming an element of the bore as the axis of abcissæ and a line perpendicular to it through the vertex of the parabola as the axis of ordinates, we express the equation of parabolic rifling as developed on a plane surface,

$$y = k(b + u)^2 = R\varphi,$$

where b is the distance of the origin of the rifling from the vertex of the parabola, and u the distance of any section of the bore from the origin of rifling.

We have

$$R\frac{d\varphi}{dt} = 2k(b+u)\frac{du}{dt} = 2k(b+u)v,$$

$$\frac{d^2\varphi}{dt^2} = \frac{2k}{R}\left((b+u)\frac{d^2u}{dt^2} + v^2\right),$$

where v denotes the velocity of the projectile at the point corresponding to the abscissa $b+u$. Substituting this derived value of $\frac{d^2\varphi}{dt^2}$ in equation (24), we obtain

$$\frac{P}{g}\frac{d^2u}{dt^2} = \frac{N}{b+u}\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{2k} - \frac{p}{g}\frac{v^2}{b+u}.$$

Remembering that $\frac{d^2u}{dt^2} = \frac{d^2x}{dt^2}$, and equating the second member of the last and (22), we find

$$N = \frac{qP(b+u) + \frac{p}{g}v^2}{\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{2k} + (b+u)(\sin\theta + f\cos\theta)} \quad . \quad . \quad (28)$$

For small values of θ we have

$$N = \mu qP\tan\theta + 2k\mu\frac{pv^2}{g}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

bearing in mind that

$$\tan\theta = \frac{dy}{du} = 2k(b+u).$$

13. The element of the work expended in overcoming the friction of the rotating band of the projectile over the rifling will be

$$fN\cos\theta\,dx,$$

or, θ being a small angle,

$$fN dx,$$

where x denotes the distance of any section of the bore from its base, expressed in calibres.

Substituting for N in this equation its value as given by formula (26), we obtain the work expended in overcoming the friction of the rotating band, for rifling of uniform twist.

$$fC\int_0^U qPdx, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

where

$$C = \frac{\mu \tan\theta \sec\theta}{1 - f\tan\theta + \mu(\tan\theta + f)\tan\theta},$$

or, approximately,

$$C = \mu \tan\theta,$$

U being the distance traversed by the projectile in the bore of the gun. Without sensible error, we may substitute for the integral in formula (30) the muzzle energy of the projectile; whence the work expended in overcoming friction becomes

$$fC\frac{pV^2}{2g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

Remembering that for parabolic rifling

$$\tan\theta = \frac{dy}{du} = 2k(b+u),$$

we may denote the work expended in overcoming the friction of the rotating band over the rifling by the expression (formula 29)

$$2f\mu k\int_0^U qP(b+u)\,dx + \frac{2pk}{g}f\mu\int_0^U v^2dx.$$

Having P and v as functions of x* we may determine the integrals found in the last formula either by integrating them directly or by calculating their values with the aid of quadrature formulæ, the quantities P and v^2 being expressed as functions of the variable x.

In view of the difficulty of calculating these quantities in the manner indicated, we deduce the following approximate method of determining the work expended in overcoming friction for the case under consideration.

* The relation between the variables x and u is so simple that I have considered it unnecessary to introduce it.

For small values of θ we have $\cos\theta - f\sin\theta = 1$ and (formula 24)

$$\frac{p}{g}\frac{d^2\varphi}{dt^2} = \frac{N}{\mu R}.$$

Remembering that

$$\frac{d^2\varphi}{dt^2} = \frac{d\omega}{dt} \quad \text{and} \quad \omega = \frac{d\varphi}{dt},$$

we have

$$\frac{d^2\varphi}{dt^2} = \omega\frac{d\omega}{d\varphi},$$

and

$$\frac{p}{g}\omega d\omega = \frac{N}{\mu R}d\varphi.$$

Integrating the latter expression between the limits $\omega = 0$ and $\omega = \omega_U$; $\varphi = 0$ and $\varphi = \varphi_U$, we obtain, for rifling of uniform twist,

$$\frac{p}{2g}\omega_U^2 = \frac{1}{\mu R}N_c\varphi_U,$$

where N_c denotes the mean pressure of the rotating band upon the driving edge; whence, since $y_U = R\varphi_U = U\tan\theta$, we find

$$N_c = \frac{p\mu R^2}{2g}\frac{\omega_U^2}{y_U} = \frac{p\mu R^2}{2g}\frac{\omega_U^2}{U\tan\theta}. \quad . \quad . \quad . \quad (32)$$

We will apply this latter formula to the case of parabolic rifling. Having

$$y = k(b+u)^2,\ \tan\theta = 2k(b+u) \quad \text{and} \quad y = \frac{(b+u)\tan\theta}{2},$$

and denoting the ordinates corresponding to the origin of rifling and rifling at the muzzle by y_1 and y_2, and the inclinations of the rifling at the corresponding points by θ_1 and θ_2, we have

$$Y_U = y_2 - y_1.$$

If the ordinate y_1 corresponds to the abscissa b, then y_2 corresponds to $b + U$; therefore

$$y_2 = \frac{(U+b)\tan\theta_2}{2},\ y_1 = \frac{b\tan\theta_1}{2},$$

and

$$y_2 - y_1 = \tfrac{1}{2}(U\tan\theta_2 + b(\tan\theta_2 - \tan\theta_1)),$$

but since

$$\tan \theta_2 = 2k\,(U + b) \text{ and } \tan \theta_1 = 2kb\,,$$

we have

$$b = \frac{U \tan \theta_1}{\tan \theta_2 - \tan \theta_1}\,,$$

whence

$$Y_U = y_2 - y_1 = \frac{U}{2}\,(\tan \theta_2 + \tan \theta_1)\,.$$

Denoting the mean pressure of the rotating band of the projectile upon the driving edge of the rifling by N_c', we find (formula 32)

$$N_c' = \frac{p\mu R^2}{2g}\,\frac{2\omega_U^2}{U\,(\tan \theta_2 + \tan \theta_1)}\,,$$

or

$$N_c' = N_c\,\frac{2 \tan \theta_2}{\tan \theta_2 + \tan \theta_1}\,. \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

Remembering the preceding deduction (31), and making certain admissions, we obtain an approximate expression for the work expended in overcoming the friction of the rotating band against the parabolic rifling,

$$C'\frac{pV^2}{2g}\,, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

where

$$C' = \frac{2f\mu \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu\,(\tan \theta_2 + f) \tan \theta_2}\,.\,\frac{1}{\tan \theta_2 + \tan \theta_1}\,,$$

or (formula 27)

$$f\mu\,\frac{2 \tan^2 \theta_2}{\tan \theta_2 + \tan \theta_1}\,\frac{pV^2}{2g}\,.$$

Assuming the coefficient of friction as 0.2, we have

$$\left.\begin{aligned} v_2 &= C', \\ \text{or} \qquad v_2 &= f\mu\,\frac{2 \tan^2 \theta_2}{\tan \theta_2 + \tan \theta_1} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

For rifling of uniform twist, θ_1 must be placed equal to θ_2 in the last expression.

14. We shall deduce expressions for calculating the velocity of the projectile at any section of the bore in front of that at which the maximum pressure is developed.

Let the abscissa x correspond to the section considered; then the work accomplished by pressure of the gases upon the base of the projectile, from this section of the bore to the muzzle, will be (formula 16)

$$\int_x^X P dx = \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_x^x .$$

This work is expended in imparting accelerating and rotating impulses to the projectile and in overcoming the friction of the rotating band over the rifling; whence

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \frac{q \cdot 2R}{1+\nu} \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_x^x . \quad (36)$$

Denoting the second member of this equation by M, we obtain the expression

$$\frac{v}{V} = \sqrt{1 - \frac{2gM}{pV^2}} , \quad . \quad . \quad . \quad . \quad . \quad (37)$$

suitable for calculating velocities of the projectile at various points along the bore. Velocities of the projectile, from the instant corresponding to the origin of motion to that at which the pressure reaches a maximum, may be determined approximately by formula (15) and by aid of the tables appended to paragraph 6.

15. We shall deduce expressions for determining the times of motion of the projectile in the bore of the gun, taking the point at which the pressure reaches a maximum as the origin.

Denoting by t' the elapsed time, reckoned from the instant the shell reaches the section of the bore corresponding to the maximum pressure, we have

$$dt' = 2R \cdot \frac{dx}{v} ,$$

where x is the distance of the section of the projectile from the base of the bore, expressed in calibres, and $2R$ the calibre, expressed in the same lineal units as the velocity v of the projectile.

Integrating this last expression between the limits $t' = 0$ and $t' = t'$, $x = x_m$ and $x = x$, we obtain

$$t' = 2R \int_{x_m}^{x} \frac{dx}{v} . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

We deduce v as a function of x from equation (36) of the preceding section. We have

$$v = V\sqrt{n_1 - \frac{n_2}{x^{0.4}} - \frac{n_3}{x^{1.4}} - \frac{n_4}{x^{2.4}}}, \quad . \quad . \quad . \quad (39)$$

where

$$n_1 = 1 + \frac{2Rq}{1+\nu}\cdot\frac{a}{0.4X^{0.4}}\left(1 + \frac{0.4}{1.4}\frac{b}{X} - \frac{0.4}{2.4}\frac{c}{X^2}\right)\frac{2g}{pV^2};$$

$$n_2 = \frac{2R.q}{1+\nu}\cdot\frac{a}{0.4}\frac{2g}{pV^2}\ ;\ n_3 = \frac{2Rq}{1+\nu}\cdot\frac{ab}{1.4}\frac{2g}{pV^2}\ ;$$

$$n_4 = -\frac{2R.q}{1+\nu}\frac{ac}{2.4}\frac{2g}{pV^2}\ .$$

Substituting in the integral (38) a second variable z for the independent variable, so chosen that $z = \frac{1}{x^{0.2}}$, we reduce the original integral to the form

$$t' = 2R\int_{x_m}^{x}\frac{dx}{v} = \frac{2R}{0.2}\cdot\frac{1}{V}\int_{z}^{z_m}\frac{dz}{z^6\sqrt{n_1 - n_2z^2 - n_3z^7 - n_4z^{12}}},$$

where the upper index z_m correponds to x_m.

The time t' is expressed by this solution in the form of an ultra-elliptic integral, the calculation of values of which is laborious; but in view of the simplicity of the calculation of the velocity v, by formula (37), we may very easily determine, and with sufficient practical accuracy, the time t' for values of the function $\frac{1}{v}$. In effecting this we employ the quadrature formula of the Academician P. L. Tchebisheff. For calculating intervals of time corresponding to a travel of projectile equal to one or two calibres, or to two or three calibres at the muzzle, all that is required is the determination of three or four values of the quantity $\frac{1}{v}$. By Tchebisheff's method, the value of the expression under the integral sign is calculated, not for equidistant intervals of path, but for intervals distributed as follows :

We have, from Tchebisheff's formula,

$$l_1' = 2R\int_{x'}^{x''} \frac{dx}{v} = \frac{l}{n}\left(\frac{1}{v_1} + \frac{1}{v_2} + \cdots + \frac{1}{v_n}\right) \cdot 2R, \quad (39)_1$$

where $l = (x'' - x')$.

When $n = 3$, the velocities should be calculated

$$\text{for } x_1 = x' + [\bar{1}.1666]\, l$$
$$\text{" } x_2 = x' + [\bar{1}.6990]\, l$$
$$\text{" } x_3 = x' + [\bar{1}.9313]\, l$$

For $n = 4$, velocities should be calculated

$$\text{for } x_1 = x' + [\bar{1}.0105]\, l$$
$$\text{" } x_2 = x' + [\bar{1}.6087]\, l$$
$$\text{" } x_3 = x' + [\bar{1}.7737]\, l$$
$$\text{" } x_4 = x' + [\bar{1}.9530]\, l$$

The quantities in brackets are logarithms.

Times of movement of the projectile from the origin to the instant when the maximum pressure is developed in the bore may be determined approximately by formula $(15)_1$ with the aid of the tables given in paragaph 6.

16. The members of the second part of equation (18) were determined from coefficients of equation (6) that were calculated from firings of the light and the 4.2-inch guns.

Calculated results show that for most cases the value of the second member of the equation falls somewhat short of that of the energy of the projectile at the muzzle. The cause of this inequality was stated in paragraph 3.

In a succeeding paragraph will be explained a way by which it is found possible to compute pressures at various points along the bore under the assumption that the work performed by the powder gases exceeds the muzzle energy of the projectile by a certain determined quantity.

We will conclude the present section with an example—the calculation of the second member of equation (18) by utilization of data from the case discussed paragraph 5.

From the results of firings of the 4.2-inch gun with a charge of 4 lbs. 10 oz. of Okhta smokeless powder and a $39\frac{3}{4}$-lb. projectile, the coefficients in the equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

were calculated as follows :

$$\log a = 4.4220\,;\ \log b = 1.3235,\ \text{and}\ \log c = 2.1931.$$

In order to determine the second member of (18), it is necessary to know, besides the above data from paragraph 5, the distance u_m, the travel of the projectile from its seat to the point of maximum pressure; and the quantity q.

In the case under consideration, we have

$$u_m = 12.1 \text{ in. and } X = \frac{142.7}{4.2}.$$

The area of the base of the shell and rifling is 15.41 sq. in., whence, taking the pressure of one atmosphere as 16.278 lbs., we have

$$\log q = 2.37327,$$

and the calibre $2R = 4.2$ inches.

For convenience in computation we divide the second member of equation (18) by $\frac{pV^2}{2g}$.

Bearing the above data in mind, and placing $p = 39.75$ lbs., $V = 1796$ ft. and $P_m = 1742$, we have

$$\frac{2gQ}{pV^2} = 0.1743,$$

and

$$q.2R\left\{\frac{a}{0.4x^{0.4}}\left(1 + \frac{0.4}{1.4}\frac{b}{x} - \frac{0.4}{2.4}\frac{c}{x^2}\right)\right\}_X^{x_m}\frac{2g}{pV^2} = 0.7989\,;$$

whence the sum

$$0.1743 + 0.7989 = 0.9732$$

proves less than unity; *i. e.*, the work performed by pressure of

the powder gases is something less, as calculated, than the energy of the projectile, $\frac{pV^2}{2g}$, at the muzzle. The reason of this circumstance has been already explained.

§ III.

Determination of Curves of Pressure, Velocity and Time, from Maximum Bore Pressure and Muzzle Energy of Projectile.

17. From the formula for pressure given in paragraph 4, we may calculate the coefficients A and B in formula (5) when the maximum pressure in the bore and the muzzle energy of the projectile are given.

For the full solution of this question the form of rifling should be given in addition to the above, and the point for which the pressure is a maximum should be determined.

We may determine u_m approximately from an inspection of Tables I, II, III, IV and V.

Tables III and IV show that for coarse grained black powder the maximum pressure corresponds to a movement of the shell of about 2.65 in. = 0.77 calibre for the light gun, and to a distance of 4.1 in. = 0.98 calibre for the 4.2-inch; we find from Table V that for prismatic powder of density 1.69 the corresponding extent of travel is about 6.9 in. = 1.2 calibres for the 6-inch gun of 190 poods weight. When charges of smokeless powder are employed, the point of maximum pressure moves towards the muzzle. The following table shows the approximate values of u_m, as obtained from actual firing of smokeless powders under various conditions.

Designation of Gun.	Kind of Powder.	u_m		Maximum Bore Pressure.	Lengths of Powder Chamber.
		in.	calibres.	atmospheres.	in.
Light Gun.	Gun cotton.	9.65	2.82	about 1600	9.35
4.2-inch gun.	Gun cotton, thickness of strip .032 inch to .035 inch.	12.1	2.88	from 1700 to 1750	14.9
		14.1	3.36		16.9
		16.7	3.98	from 1000 to 1500	16.9
		16.6	3.95		12.4
	Gun cotton, thickness of strip .0425 inch to .045 inch.	16.7	3.98	from 1600 to 1700	16.9
		between 16.7 and 26.1	between 3.98 and 6.21	about 900	
	Rottweil nitro-glycerine.	8.3	1.98	about 1750	16.9
		12.1	2.88	about 1000	
6-inch gun.	Gun cotton and Rottweil nitro-glycerine.	17.9	3.0	from 1000 to 1850	24.9

It is evident from the above that as the breech pressure diminishes in the 4.2 gun, the section of the bore corresponding to the maximum pressure moves towards the muzzle. Although this circumstance is not so apparent in the cases of the light gun and the 6-inch, nevertheless, with charges of gun cotton powders developing breech pressures of from 1000 to 1300 atmospheres, the gauges placed directly in front of those giving the maximum readings (15.15 in. = 4.43 calibres for the light gun, and 23.3 in. = 3.9 calibres for the 6-inch gun) themselves afford readings which are close to the maxima; so it becomes evident that the actual maximum pressures developed correspond to sections of the bore between the two.

It follows from the above that for charges of gun cotton smokeless powders developing breech pressures of from 1600 to 1800 atmospheres, the maximum pressure in the bore occurs after the projectile has traversed a distance of from three to four calibres, according to the thickness of the powder strip; and that with reduced charges, a distance of from four to six calibres, according to the thickness of the powder strip; so that in the first case $u_m = 3$ or 4 calibres, and in the second, 4 or 6 calibres.

In the case of charges of nitro-glycerine powders experimented with in the 4.2 gun, u_m was found to be two calibres for full charges and 3 calibres for reduced charges. With the nitro-glycerine powders tried in the 6-inch gun $u_m = 3$ calibres for full and reduced charges; but the powder did not correspond to the length of the bore of the gun, nor were the charges completely consumed. Having the quantity u_m and the dimensions of the powder chamber, x_m in equation (5) may be calculated.

Sarrau has shown theoretically that the travel of the projectile from its seat to the point of maximum pressure in the bore is

$$u_m = 0.6u_o, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

where u_o is defined by formula (11), which we may express in the form

$$u_o = l\left(1 - \frac{\Delta}{\delta}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (B)$$

where l denotes the reduced length of the powder chamber.

It is evident from the formulæ that u_m decreases with the decrease in weight of the charge, independently of variation in bore pressure and of kind of powder, which is contrary to experience obtained by practice.

Thus, for example, from (*A*) and (*B*) we find, for a charge of 4 lbs. 15 oz. of the Okhta smokeless powder, in the 4.2-in. gun,

$$u_m = 11.1 \text{ in.},$$

and for $5\frac{3}{4}$ pounds of an Okhta powder specially designed for the same gun,

$$u_m = 10.4 \text{ in.},$$

while for the latter case actual firings prove that

$$u_m = 16.7 \text{ in.},$$

which is greater than the result practically obtained for 4 lbs. 15 oz. of the Okhta powder, which gives

$$u_m = 12.1 \text{ in.}$$

In view of the nature of results above considered, this might have been expected.

It was stated above that with the diminution of weight of charge and consequently with diminution in magnitude of pressure, the quantity u_m increased for one and all varieties of powder; but it is easy to see that while the values calculated by formulæ (*A*) and (*B*) increase with diminution of charge, they do not do so in the degree that practice determines them to do.

Thus, for example, the charge of 3 lbs. 11 oz. of Okhta smokeless powder, fired from the 4.2-inch gun, gives by calculation

$$u_m = 12.0 \text{ in.},$$

which is greater than for the charge of 4 lbs. 15 oz., but markedly less than the practically determined value

$$u_m = 16.7 \text{ in.}$$

Firing projectiles of different weights from the 4.2-in. gun, with the same charge of $4\frac{40}{96}$ lbs. of Okhta smokeless powder proves that with the diminution of these weights the maximum pressure diminishes, and that at the same time the section of the bore corresponding to the maximum pressure moves towards the muzzle; that is, u_m increases. But by formulæ (*A*) and (*B*) the quantity u_m should, under existing conditions, remain unaltered.

As the result of practical trial, and from the nature of the question under consideration, it follows that the value of u_m depends on the maximum bore pressure, the weight of the charge, the dimensions of the strip and the particular properties of the powder under consideration. The number of experimental results obtained up to the present is not sufficient to permit of the nature of this relation being definitely expressed.

18. To determine the pressure curve, as defined by formula (5),

$$P = \frac{A}{x^{1.4}}\left(1 - \frac{1.4}{3.4}\left(\frac{x_m}{x}\right)^2\right) + \frac{B}{x^{2.4}}\left(1 - \frac{2.4}{3.4}\frac{x_m}{x}\right), \quad . \quad (5)$$

the coefficients (A) and (B) must be found, and for determining these, two equations are required. We may obtain one of these equations from (5) by putting $x = x_m$ and substituting for P its corresponding value $P = P_m$. This pressure may, without sensible error, be assumed as equal to the breech pressure. The quantity x_m is the reduced length of the powder chamber corresponding to a diameter equal to the calibre of the gun, and increased by the distance u_m. This latter quantity is determined under the conditions stated in the preceding section.

We have, then,

$$P_m = \frac{A}{x_m^{1.4}}\left(1 - \frac{1.4}{3.4}\right) + \frac{B}{x_m^{2.4}}\left(1 - \frac{2.4}{3.4}\right). \quad . \quad . \quad (40)$$

The second equation for the determination of (A) and (B) is supplied by the condition that the work developed by pressure is equal to $(1+v)\frac{pV^2}{2g}$; that is,

$$(1+v)\frac{pV^2}{2g} = q \cdot 2R\int_{x_m}^{X} P\,dx + Q,$$

where Q is determined by formula (17).

Integrating the first part of the second member of the last equation by substituting for P its value from (3), we have

$$\int_{x_m}^{X} P\,dx = \int_{x_m}^{X}\left(\frac{A}{x^{1.4}} + \frac{B}{x^{2.4}} + \frac{C}{x^{3.4}}\right)dx$$

$$= \left(\frac{A}{0.4x^{0.4}} + \frac{B}{1.4x^{1.4}} + \frac{C}{2.4x^{2.4}}\right)_X^{x_m};$$

but (formula 4),

$$C = -\frac{1.4}{3.4} x_m^2 A - \frac{2.4}{3.4} x_m B,$$

whence

$$\int_{x_m}^{x} P dx = \left\{ \frac{A}{0.4 x^{0.4}} \left(1 - \frac{0.4}{2.4} \frac{1.4}{3.4} \left(\frac{x_m}{x} \right)^2 \right) + \frac{B}{1.4 x^{1.4}} \left(1 - \frac{1.4}{2.4} \frac{2.4}{3.4} \frac{x_m}{x} \right) \right\}_{x}^{x_m},$$

and

$$(1+\nu)\frac{pV^2}{2g} = q \cdot 2R \left\{ \frac{A}{0.4 x^{0.4}} \left(1 - \frac{0.4}{2.4} \frac{1.4}{3.4} \left(\frac{x_m}{x} \right)^2 \right) + \frac{B}{1.4 x^{1.4}} \left(1 - \frac{1.4}{3.4} \frac{x_m}{x} \right) \right\}_{x}^{x_m} + Q, \quad . \quad . \quad (41)$$

where

$$\left. \begin{aligned} \nu &= \nu_1 + \nu_2 \\ \nu &= \mu \tan^3 \theta_2, \text{ and } \nu_2 = C' \end{aligned} \right\} \quad . \quad . \quad . \quad . \quad . \quad (42)$$

Solving (40) and (41), we find A and B, and then, by substituting them in (5), we are enabled to ascertain the pressures at various points along the bore.

For convenience in computation, equations (40) and (41) may be expressed by use of the abbreviations

$$\left. \begin{aligned} a &= \frac{[\bar{1}.76956]}{P_m x_m^{1.4}}; \quad \beta = \frac{[\bar{1}.46853]}{P_m x_m^{2.4}} \\ a' &= \frac{2g}{pV^2} \cdot \frac{1}{0.4} \left\{ \frac{1}{x^{0.4}} \left(1 - [\bar{2}.83650] \left(\frac{x_m}{x} \right)^2 \right) \right\}_{x}^{x_m} q.2R \\ \beta' &= \frac{2g}{pV^2} \frac{1}{1.4} \left\{ \frac{1}{x^{1.4}} \left(1 - [\bar{1}.61465] \left(\frac{x_m}{x} \right) \right) \right\}_{x}^{x_m} q.2R \\ \gamma &= 1 + \nu - \frac{2gQ}{pV^2}, \end{aligned} \right\} \quad . \quad (43)$$

where the numbers included in brackets represent logarithms.

By the use of the substitutions indicated, equations (40) and (41) assume the form

$$\left.\begin{aligned} \alpha A + \beta B &= 1 \\ \alpha' A + \beta' B &= \gamma \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (44)$$

where

$$\left.\begin{aligned} A &= \frac{\beta' - \gamma\beta}{\alpha\beta' - \alpha'\beta} = \frac{\gamma\left(\frac{\beta}{\beta'}\right) - 1}{\alpha'\left(\frac{\beta}{\beta'}\right) - \alpha} \\ B &= \frac{\alpha\gamma - \alpha'}{\alpha\beta' - \alpha'\beta} = \frac{\frac{\alpha'}{\beta'} - \gamma\left(\frac{\alpha}{\beta'}\right)}{\alpha'\left(\frac{\beta}{\beta'}\right) - \alpha} \end{aligned}\right\} \quad \ldots\ldots \quad (45)$$

19. We shall apply the above formulæ to the determination of curves of pressures, velocities and times in the following examples.

Example 1.—It is found by trial that the pressure in the bore of the 4.2-inch gun with a charge of 4 lbs. 10 oz. of Okhta smokeless powder (thickness of strip .035 in.) attains its maximum at a distance corresponding to a travel of projectile of 12.1 inches. The pressure at this section of the bore is $P_m = 1742$ atmospheres. Under these conditions there is obtained the initial velocity $V = 1796$ f. s.; the projectile weighing 39.75 lbs.

The length of the powder chamber is 16.9 inches. The rifling of the 4.2-inch gun is parabolic, with a twist of one in twenty-five calibres at the muzzle and one in seventy-four and six-tenths at the origin of rifling. For the cast iron projectiles used in the trials, $\mu = 0.53$ inches.

To calculate the coefficient ν, we have

$$\nu_1 = \mu \tan^2 \theta_1 = 0.53 \left(\frac{\pi}{25}\right)^2 = 0.008837,$$

$$\nu_2 = C' = \frac{2f\mu \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.02020,$$

$$\nu = 0.02857.$$

It was shown in paragraph 5 that, in order to obtain the reduced length of any section of the bore of the 4.2-inch gun, it was necessary

to increase the length of the powder chamber by 6.68 inches, the compensation for the reduced length of the powder chamber with its slope. Therefore

$$x_m = \frac{16.9 + 12.1 + 6.68}{4.2}$$

$$X = \frac{142.7}{4.2}.$$

The value of q for the 4.2-inch was calculated in paragraph 16 as

$$\log q = 2.37327.$$

Substituting the above data in the formulæ of the preceding number, we calculate

$$\log \alpha = \bar{5}.22767\,;\ \log \beta = \bar{7}.99747\,;$$

$$\log \alpha' = \bar{5}.20040\,;\ \log \beta' = \bar{7}.83372\,;$$

$$\frac{2gQ}{pV^2} = 0.17434\,;\ \gamma = 1.02857 - 0.17434 = 0.85423\,;$$

$$\log \gamma = \bar{1}.93158\,;$$

$$\log A = 4.59401\,;\ \log B = 5.52971.$$

Having ascertained A and B, we may calculate pressures at various points along the bore by formula (5).

To employ this formula, we reduce it to the form

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right); \quad \ldots \quad (6)$$

and, by relation (7), we obtain the coefficients in the equation

$$\log a = 4.59401,$$
$$\log b = 0.93570,$$
$$\log c = 1.91078.$$

For determining velocities, we employ the expression

$$(1+v)\left(\frac{pV^2}{2g} - \frac{pv^2}{2g}\right) = \left\{\frac{[4.9919]}{x^{0.4}}\left(1 + \frac{[0.3917]}{x} - \frac{[1.1327]}{x^2}\right)\right\}_X^{x_m} q.2R.$$

The time t' is determined by formula $(39)_1$ of paragraph 15.

Denoting by t_m the time of movement of the projectile, from the instant of its displacement to the instant at which the maximum pressure is developed in the bore, we have

$$t = t_m + t',$$

as measured from the origin of motion. The time t_m is determined by formula $(15)_1$ of paragraph 6.

The pressures, velocities and times contained in the following table are calculated by utilization of the preceding formulæ. The observed pressures and initial velocities are added.

Distance of Section of Bore from Base of Bore.	Pressures.		Calculated Velocities.	Calculated Times.
	Observed.	Calculated.		
in.	atm.	atm.	ft. sec.	sec.
29.0	1693	1742*	739	0.00468
33.6	1658	1681	891	0.00515
42.0	1490	1447	1093	0.00586
53.2	1154	1147	1286	0.00665
61.8	872	965	1388	0.00719
85.4	509	637	1582	0.00851
127.4	323	363	1775	0.01051
136.0		334	1796	0.01099

The above table shows that the calculated pressures exceed the actual pressures only for those gauges placed in the portions of the bore nearest the muzzle, a result that might have been expected from what has been said above. The curves for pressures, velocities and time intervals are shown in Plate I, the pressure curve being denoted by the broken line. Those portions of the curve extending from the origin of motion to the point corresponding to

* The maximum pressure is assumed as identical with that calculated by use of formula (5). It is approximately equal to the registered breech pressure of 1722 atmospheres.

the maximum pressure are determined by ordinates whose values are calculated by the use of the formulæ and table contained in paragraph 6.

Example II.—It is experimentally ascertained that the pressure in the bore of the 3.42-inch gun, with a charge of 1 lb. 11 oz. of Okhta smokeless powder attains its maximum for a travel of the projectile of 9.65 inches, P_m then being 1660 atmospheres. Under these conditions an initial velocity $V = 1673$ feet is obtained, the projectile weighing 16.75 lbs. The length of the powder chamber is 9.35 inches.

The rifling of the 3.42-inch gun is of progressive curvature, one turn in 40 calibres at the muzzle and one turn in 370 calibres at the origin; $\mu = 0.53$ for the projectile used.

To calculate the coefficient ν, we have

$$\nu_1 = \mu \tan^2 \theta_2 = 0.53 \left(\frac{\pi}{40}\right)^2 = 0.00327,$$

$$\nu_2 = C' = \frac{2f\mu \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01514,$$

and

$$\nu = 0.01841.$$

In expressing the distance of any section of the bore from the base of the bore, it is necessary to increase the distance measured along the axis of the gun by 2.36 inches (compensation for "reduced length").

Therefore

$$x_m = \frac{9.35 + 9.65 + 2.36}{3.425}$$

and

$$X = 22.11 \text{ calibres.}$$

The area of cross section of shell and rifling is 9.640 sq. in..

$$\log q = 2.19568.$$

By the formula of the preceding section, we find

$$\log \alpha = \bar{5}.43653; \quad \log \beta = \bar{6}.34056;$$

$$\log \alpha' = \bar{5}.39025; \quad \log \beta' = \bar{6}.17165;$$

$$\frac{2gQ}{pV^2} = 0.24085\,;\quad \gamma = 1.01841 - 0.24085 = 0.77756\,;$$

$$\log \gamma = \bar{1}.89073\,;$$

$$\log A = 4.21931\,;\quad \log B = 5.39882.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right). \quad . \quad . \quad . \quad . \quad . \quad (6)$$

become

$$\log a = 4.21931,$$
$$\log b = 1.17951,$$
$$\log c = 1.91682.$$

For determining the velocity of the projectile we have the expression

$$\frac{PV^2}{2g} - \frac{pv^2}{2g} = \left\{\frac{[4.6172]}{x^{0.4}}\left(1 + \frac{[0.6349]}{x} - \frac{[1.1387]}{x^2}\right)\right\}_x^{x_m} \frac{q.2R}{1+v}.$$

Formulæ $(15)_1$ and $(39)_1$ serve to determine the times of motion of the projectile at points along the bore.

The calculated results are given in the following table:

Distance of Section of Bore from Base of Bore.	Pressures.		Calculated Velocities.	Calculated Times.
	Observed.	Calculated.		
in.	atm.	atm.	ft. sec.	sec.
19.0	1588	1660*	813	0.00338
24.5	1489	1468	1045	0.00387
34.5	1063	996	1300	0.00458
48.0	441	633	1492	0.00539
66.5	307	384	1636	0.00637
73.4		329	1673	0.00672

The deductions to be made from this table are identical with those to be had from Example I.

The curves of pressures, velocities and times are shown in Plate II, the pressure curve being denoted by the broken line. Those

* This pressure is assumed as identical with that given by formula (5).

portions of the curve extending from the seat of the projectile to the point of maximum pressure were determined as explained in paragraph 6.

Example III.—Upon firing a charge of 12 lbs. of Okhta smokeless powder from the 6-inch gun of 190 poods weight (7600 lbs.), a maximum pressure $P_m = 1798$ atm. was realized, which corresponded to a travel of projectile along the bore of 17.9 inches. The initial velocity $V = 1835$ ft. sec. It is required to determine the curves of pressure, velocities and intervals of time. The projectile weighed 81.25 lbs. and the length of the powder chamber was 24.9 inches. The rifling of the gun is parabolic, the inclination at the muzzle being $\theta_2 = 4°$ (one turn in 45 calibres) and at the origin of rifling $\theta_1 = 1°47'$.

$\mu = 0.53$ for the 6-inch cast iron projectile of 2.5 calibres' length. Therefore

$$\nu_1 = \mu \tan^2 \theta_2 = 0.53 \tan^2 4° = 0.002591,$$

$$\nu_2 = C' = \frac{2\mu f \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01030,$$

and

$$\nu = \nu_1 + \nu_2 = 0.01289.$$

In expressing the distance of any section of the bore from the base of the bore, the distance as measured along the axis of the gun must be increased by 2.15 inches, so as to make the reduced length of the powder chamber and slope correspond to a diameter of chamber equal to that of the bore. We then have

$$x_m = \frac{24.9 + 17.9 + 2.15}{6},$$

and

$$X = \frac{114 + 2.15}{6} = 19.36 \text{ calibres.}$$

The area of the base of the projectile and rifling is 29.88 sq. in.,

$$\log q = 2.67220.$$

By the formula of the preceding number, we find

$$\log \alpha = \bar{5}.29036\,; \quad \log \beta = \bar{6}.11475\,;$$

$$\log \alpha' = \bar{5}.19683\,; \quad \log \beta' = \bar{7}.93578\,;$$

$$\frac{2gQ}{pV^2} = 0.24842;\quad \gamma = 1.01189 - 0.24842 = 0.76347;$$

$$\log \gamma = \bar{1}.88279;$$

$$\log A = 4.55654;\quad \log B = 5.35821.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

become

$$\log a = 4.55654,$$
$$\log b = 0.80167,$$
$$\log c = 1.75286.$$

To determine the velocities of projectile, we employ

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \left\{\frac{[4.9544]}{x^{0.4}}\left(1 + \frac{[0.2577]}{x} - \frac{[0.9748]}{x^2}\right)\right\}_x^{x_m} \frac{q \cdot 2R}{1+\nu},$$

Formulæ $(15)_1$ and $(39)_1$ are used to determine the times of movement of the projectile along the bore.

Calculated results are arranged in the following table:

Distance of Section of Bore from Base of Bore.	Calculated.		Calculated Times.
	Pressures.	Velocities.	
in.	atm.	ft. sec.	sec.
42.8	1798	910	0.00560
48.2	1744	1059	0.00605
57.0	1551	1246	0.00669
63.0	1411	1358	0.00707
72.0	1216	1485	0.00760
79.6	1103	1572	0.00802
93.0	883	1696	0.00870
110.0	703	1812	0.00953
114.0	667	1835	0.00971

Curves of pressures, velocities and intervals of time are traced in Plate III. The ordinates of these curves, from the origin of motion to the point corresponding to maximum pressure in bore, are calculated by the use of the table and the formula given in paragraph 6. The measured pressures are also shown upon this sheet.

20. In designing guns, it is necessary to have some way of estimating the pressure of the powder gases at various points along the bore. The method herein described may be employed as an approximate solution of the question, when the breech pressure and muzzle energy of the projectile are given and the form of rifling is stated.

The form of rifling is required for the calculation of the coefficient ν. Assuming the maximum bore pressure P_m as equal to the pressure at the breech, and determining approximately the section of the bore corresponding to this maximum pressure (paragraph 17), we obtain the full data for the solution of the question within the prescribed limits.

Having developed the curve of pressures, the opposing resistances of the gun, which should be distributed according to load, may be calculated. With us it is customary to make the strength of resistance equal to one and one half times the load; and in the case of heavy guns, twice the load.

We shall proceed to apply the above explained method to the determination of curves of pressures, velocities and intervals of time in the case of a gun for which pressures have not been determined by means of gauges ranged along the bore.

Example IV.—As the result of trials made by us with a 6-in. Q. F. Canet gun of 50 calibres' length, we find a breech pressure of 2250 atmospheres, corresponding to an initial velocity $V = 2620$ ft. sec., the weight of the projectile being 101 lbs. Such results may be obtained by employing a charge of about $27\frac{1}{2}$ lbs. of Okhta smokeless powder. The curves of pressures, velocities and times are required.

The length of the powder chamber is 40.44 in.; the rifling of this gun is parabolic, the angle of inclination at the muzzle being $\theta_2 = 6°$, and the initial angle $\theta_1 = 2° 30'$. The cast iron projectile for the Canet gun has a length of about $3\frac{1}{2}$ calibres, and $\mu = 0.55$.

Therefore

$$v_1 = \mu \tan^2 \theta_2 = 0.00607,$$

$$v_2 = C' = \frac{2\mu f \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01712,$$

and

$$v = v_1 + v_2 = 0.02319.$$

On the basis of the conditions stated in paragraph 17, we assume that the maximum bore pressure P_m equals the breech pressure of 2250 atmospheres and is developed in the bore at a point corresponding to a travel of the projectile of four calibres; *i. e.*, $u_m = 24$ inches.

In expressing the distance of any section of the bore from the base of the bore, it is necessary to increase the distance measured along the axis by 3.31 inches, so as to give powder chamber and slope the reduced length corresponding to a diameter of chamber equal to the calibre of the gun. Whence

$$x_m = \frac{40.44 + 24 + 3.31}{6},$$

and

$$X = \frac{281.34 + 3.31}{6} = 47.44 \text{ calibres.}$$

The area of the base of the projectile and rifling is 28.79 sq. in.,

$$\log q = 2.67084.$$

We find from the formulæ given above

$$\log \alpha = \bar{6}.94352; \quad \log \beta = \bar{7}.58973;$$

$$\log \alpha' = \bar{6}.88352; \quad \log \beta' = \bar{7}.38762;$$

$$\frac{2gQ}{pV^2} = 0.16396; \quad \gamma = 1.02319 - 0.16396 = 0.85923;$$

$$\log \gamma = \bar{1}.93411;$$

$$\log A = 5.03497; \quad \log B = 5.09396.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

become

$$\log a = 5.03497\,,$$
$$\log b = 0.05899\,,$$
$$\log c = 1.78980\,.$$

To determine velocities of projectile, we employ the expression

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \left\{\frac{[5.4329]}{x^{0.4}}\left(1 + \frac{[\bar{1}.5150]}{x} - \frac{[1.0118]}{x^2}\right)\right\}_x^{x_m} \frac{q.2R}{1+\nu}.$$

The times of motion of projectile along the bore are calculated by formulæ $(15)_1$ and $(39)_1$.

Calculated results are given in the following table.

Distance of Section of Bore from Base of Bore.	Calculated Pressures.	Calculated Velocities.	Calculated Times.
in.	atm.	ft. sec.	sec.
40.44	0	0	0
44.44	1521	322	0.00405
48.44	1918	520	0.00480
52.44	2138	684	0.00540
56.44	2196	818	0.00579
60.44	2218	903	0.00618
64.44	2250	1048	0.00651
78.00	2113	1351	0.00745
84.92	1994	1473	0.00787
96.00	1799	1639	0.00846
110.90	1558	1816	0.00914
132.00	1284	2006	0.01006
159.41	1023	2186	0.01115
204.00	746	2394	0.01277
281.34	486	2620	0.01533

Curves of pressures, velocities and times are shown in Plate IV. The upper broken line shown upon this plate represents the strength of resistance of the gun, calculated for a limit of elasticity of 3300 atmospheres.

§ IV.

Pressure of the Driving Edge of the Rifling upon the Rotating Band of the Projectile.

21. Having determined the pressures of the powder gases and the velocities of the projectile for various points along the bore, we may ascertain the pressure of the rifling upon the rotating band of the projectile, if the equation to the curve of rifling, developed upon a plane surface, be given.

In paragraph 12 we developed formulæ suitable for determining, within the required limits of accuracy, the pressures of rifling upon rotating band in the case of parabolic rifling, (formula (29)).

$$N = \mu q P \tan\theta + 2k\mu\frac{pv^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad (29)$$

N in this formula is expressed in the same units of weight as the weight of the projectile p; the bore pressures are expressed in atmospheres, q representing the pressure of one atmosphere over the base of the projectile and rifling, taken in units of weight.

Assuming the prolongation of the bore as the axis of abscissæ and a line perpendicular to it through the vertex of the parabola as the axis of ordinates, Y, we obtain the equation of parabolic rifling developed upon a plane,

$$y = k(b+u)^2,$$

where b is the distance of the origin of rifling from the vertex of the parabola, and u the distance of any section of the bore from the origin of rifling.

The quantities b and u are expressed in the same lineal units as the velocity v and the acceleration of gravity g.

Remembering that

$$\tan\theta = 2k(b+u),$$

and substituting this last expression in formula (29), we obtain

$$N = 2k\mu q P(b+u) + 2k\mu\frac{pv^2}{g}. \quad . \quad . \quad . \quad . \quad (46)$$

Employing the data given in paragraph 19, we may calculate the pressures N upon the rotating band of the projectile in the case of the 4.2 inch gun. As supplementary to the data there found, we state that

$$k = 0.0040259, \text{ and } b = 5.68 \text{ ft.};$$

the distance of the origin of rifling from the base of the bore is 17.17 in.; the angle of inclination of rifling at the origin is $\theta_0 = 2° 38'$, and at the muzzle $\theta_1 = 7° 10'$.

Calculated results are shown in the following table:

Distance of Section of Bore from Base of Bore.	Bore Pressures P.	Velocities of Projectile v.	Pressures upon the Driving Edge of Projectile N.
in.	atm.	ft. sec.	tons.
29.0	1742	739	5.89
33.6	1681	891	6.49
42.0	1447	1093	7.09
53.2	1147	1286	7.55
61.8	965	1388	7.77
85.4	637	1582	8.26
115.5	421	1727	8.71
127.4	363	1775	8.89
136.0	334	1796	8.96

It is evident from the above table that the pressure N increases as the projectile moves along the bore and attains its greatest value at the muzzle.

In Plate I is traced the curve of pressures N, upon the rotating band, from the origin of motion of the projectile to the point corresponding to the maximum bore pressure, the pressures from the origin of motion to the point of maximum pressure being calculated for values of P and v determined by the formulæ and table of paragraph 6.

The initial angle of inclination of the rifling of the 4.2-inch gun is determined under the condition that the pressure N upon the rotating band shall be approximately equal for its values as developed at the point of maximum pressure in the bore and at the muzzle of the gun, for charges of coarse grained powder developing breech pressures of 1900 atmospheres, with projectile of $39\frac{3}{4}$ lbs. weight, and initial velocity of 1450 f. s. Under these conditions $N_m = 5.2$ tons at the point of maximum pressure, and $N_1 = 5.7$ tons at the muzzle.

The differences between the pressures upon the rotating band of the projectile at the origin of rifling and at the muzzle will be found still greater if we consider the results obtained with a charge of $5\frac{3}{4}$ lbs. of Okhta smokeless powder specially prepared for the 4.2-in. gun (thickness of strips .0425 in.). We then find for the section of the bore at which the pressure reaches its maximum

$$P_m = 1709 \text{ atm.}, \; v_m = 845 \text{ ft. sec., and } N_m = 6.4 \text{ tons,}$$

and at the muzzle

$$P_1 = 467 \text{ atm.}, \; V = 1962 \text{ ft. sec., and } N_1 = 11.1 \text{ tons.}$$

If the rifling were of constant curvature, of 25 cal. twist, that is, if $\theta = 7^\circ\, 10'$, then the greatest value of N would be found at the section of the bore corresponding to the maximum pressure.

Taking $P = 1709$ atmospheres, we have

$$N = q\mu P \tan\theta = 10.8 \text{ tons.}$$

Results show that the maximum pressure upon the rotating band is less for rifling of constant curvature than it is for parabolic rifling, according to results obtained from firing charges of $5\frac{3}{4}$ lbs. of Okhta smokeless powder. The disadvantage of progressive rifling for progressive powders arises from the fact that the initial angle of inclination of the rifling is not adapted to the conditions of the problem. The manner of determining this angle is explained below.

22. The initial angle of inclination of rifling is customarily determined under the condition that the pressure upon the rotating

band of the projectile N_m, at the point of the bore corresponding to the maximum powder pressure P_m, should be equal to the pressure upon the rotating band N_1, at the muzzle.* Denoting the angle of inclination of the rifling for the point of maximum bore pressure P_m, as θ_m, the distance of the corresponding section of the bore from the base of the bore by U, and the inclination of the rifling at the muzzle by θ_1, and remembering that

$$2k = \frac{\tan \theta_1 - \tan \theta_m}{U},$$

we obtain (formula (29)),

$$N_m = q\mu P_m \tan \theta_m + \mu \frac{p}{g} v^2_m \frac{\tan \theta_1 - \tan \theta_m}{U},$$

$$N_1 = q\mu P_1 \tan \theta_1 + \mu \frac{p}{g} V^2 \frac{\tan \theta_1 - \tan \theta_m}{U}.$$

Equating the second members of the last two equations and solving for $\tan \theta_m$, we obtain

$$\tan \theta_m = \frac{P_1 q + \frac{pV^2}{gU}\left(1 - \frac{v^2_m}{V^2}\right)}{P_m q + \frac{pV^2}{gU}\left(1 - \frac{v^2_m}{V^2}\right)} \tan \theta_1 \quad . \quad . \quad . \quad (47)$$

For a charge of 4 lbs. 10 oz. specially prepared Okhta smokeless powder, we have

$$P_m = 1742 \text{ atm.}; \quad V_m = 739 \text{ ft. sec.};$$
$$P_1 = 334 \text{ atm., and } V = 1796 \text{ ft. sec.}$$

The pressure P_m occurs at a point 29 inches distant from the base of the bore, its whole length being 136 inches; whence $U = 136 - 29 = 107$ in.

Substituting the above quantities in equation (47) and remembering that $p = 39\frac{3}{4}$ lbs., $\log q = 2.37327$, and $\theta_1 = 7° 10'$, we have

$$\theta_m = 4° 8'.$$

* If the rifling at the muzzle be of constant curvature for some portion of its length, the pressure N_1 corresponds to the point of the bore at which the parabolic rifling merges into the rifling of constant curvature.

As the distance of the origin of rifling from the base of the bore is 17.17 inches, the angle at this point becomes 3° 48′ greater than is now taken (2° 38′) in the 4.2-inch gun; for this angle

$$k = 0.002997, \text{ and } b = 12.08 \text{ ft.}$$

Substituting the latter quantities in equation (46), we obtain the pressures upon the rotating band of the projectile N for various points along the bore, as in the following table:

Distance of Section of Bore from Base of Bore.	Pressure upon Rotating Band of Projectile.
in.	tons.
29.0	7.22
33.6	7.56
42.0	7.65
53.2	7.48
61.8	7.36
85.4	7.19
115.5	7.17
127.4	7.19
136.0	7.23

It is evident from the above that for equal pressures on the rotating band in the extreme sections of the bore, the pressures in the intermediate sections change periodically in such a way that the maximum pressure (7.65 tons) is close to the value obtained for the muzzle sections.

For a charge of $5\frac{3}{4}$ lbs. Okhta smokeless powder especially prepared for the 4.2-inch gun (thickness of strip .0425 inch), we have

$$P_m = 1709 \text{ atm.}, \quad v_m = 845 \text{ ft. sec.},$$

$$P_1 = 467 \text{ atm.}, \quad V = 1962 \text{ ft. sec.},$$

$$\theta_1 = 7° 10'; \quad U = 136 - 33.6 = 102.4 \text{ in.};$$

whence, from formula (47), we obtain

$$\theta_m = 4^\circ 44',$$

and for the angle of inclination of the rifling at the origin, $4^\circ 20'$.

The pressure upon the rotating band of the projectile at sections corresponding to the maximum bore pressure and the muzzle is

$$N_m = N_1 = 8.1 \text{ tons.}$$

In the case of initial angles determined by this method there would seem to be an advantage in parabolic rifling over rifling of constant curvature.

For charges of smokeless powder developing increased initial velocities, a greater initial angle of inclination is obtained than that taken in the 4.2-inch.

In the case of initial velocities exceeding 2000 feet with the use of charges of progressive powder developing moderate bore pressures, it may be stated that the calculated initial angle of inclination of the rifling is close to the final (at the muzzle) and that the pressures upon the rotating band approximate to those afforded by rifling of constant twist; *i. e.*, the superiority of parabolic rifling over rifling of constant twist does not become apparent.

§ V.

Empirical Monomial Formulæ for Breech Pressure, Initial Velocity and Force of Powder.

23. As applying to charges of saltpetre-sulphur-charcoal powders, Sarrau has determined empirical monomial formulæ for breech pressures and initial velocities. These expressions are of great value for solving questions in interior ballistics.

There does not yet exist a sufficient amount of experimental data to permit the final determination of suitable formulæ applicable to smokeless powders. On the basis of results obtained by us, employing various charges and projectiles and various densities of loading, we are able to present approximate expressions for breech pressures and initial velocities based upon data obtained from the kinds of powder experimented with.

The formula for initial velocity is

$$V = H\frac{\Delta^{\frac{1}{4}}\tilde{\omega}^{\frac{1}{2}}}{p^{\frac{5}{16}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

and the formula for breech pressure

$$P = K\Delta\tilde{\omega}p^{\frac{3}{4}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

where Δ denotes the density of loading; *i. e.*, the ratio of the weight of the charge $\tilde{\omega}$ to the weight of water occupying a volume equal to that of the powder chamber.

Denoting the diameter of the powder chamber by D, and its length by l, we have

$$V = H'\frac{\tilde{\omega}^{\frac{3}{4}}}{D^{\frac{1}{4}}l^{\frac{1}{4}}p^{\frac{5}{16}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$P = K'\frac{\tilde{\omega}^{2}p^{\frac{3}{4}}}{D^{2}l}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

The relation between initial velocity and pressure for a given charge of smokeless powder, as determined by Longridge,* confirm our results.

In proof of the applicability of the above deduced formulæ, there are given in Table VI both experimental results and results calculated by use of the formulæ, arranged in parallel columns.

Results afforded by charge and projectile of maximum weight are employed as a basis for establishing comparisons.

Comparisons of calculated and experimentally determined values establish the fact that the proposed formulæ furnish results sufficiently accurate for practical uses.

24. Having determined for smokeless powders the characteristics H and K entering into formulæ (48) and (49), we may establish a simple relation between them and the coefficients (A) and (B) of equation (5), paragraph 18.

* "Smokeless Powder and its Influence on Gun Construction." Translated by Captain Neelus, Artillery Journal, No. 2, 1891.

Assuming the maximum bore pressure P equal to the breech pressure, we obtain (formulæ (43))

$$a = \frac{a_1}{K} \; ; \; \beta = \frac{\beta_1}{K} \; ;$$

$$a' = \frac{a_1'}{H^2} \; ; \; \beta' = \frac{\beta_1'}{H^2} \text{, and } \gamma = 1 + \nu - \gamma_1 \frac{K}{H^2} \text{,}$$

where

$$a_1 = \frac{[\bar{1}.76956]}{\Delta \tilde{\omega} p^{\frac{2}{3}} x_m^{1.4}} \; ; \; \beta_1 = \frac{[\bar{1}.46853]}{\Delta \tilde{\omega} p^{\frac{2}{3}} x_m^{2.4}} \; ;$$

$$a_1' = \frac{2g}{p^{\frac{2}{3}} \Delta^{\frac{1}{3}} \tilde{\omega}} \cdot \frac{1}{0.4} \left\{ \frac{1}{x^{0.4}} \left(1 - [\bar{2}.83650] \frac{x^2{}_m}{x^2} \right) \right\}_x^{x_m} q \, . \, 2R,$$

$$\beta_1' = \frac{2g}{p^{\frac{2}{3}} \Delta^{\frac{1}{3}} \tilde{\omega}} \cdot \frac{1}{1.4} \left\{ \frac{1}{x^{1.4}} \left(1 - [\bar{1}.61465] \frac{x_m}{x} \right) \right\}_x^{x_m} q \, . \, 2R,$$

and (formulæ (17) and (43))

$$\gamma_1 = 1.6732 \, . \, gq \Delta^{\frac{1}{3}} p^{\frac{2}{3}} u_m \, .$$

Whence (formula (45))

$$\left. \begin{aligned} A &= \frac{(1+\nu)\beta_1 H^2 - (\beta_1' + \gamma_1 \beta_1) K}{a_1' \beta_1 - a_1 \beta_1'} \\ B &= \frac{(a_1' + \gamma_1 a_1) K - (1+\nu) a_1 H^2}{a_1' \beta_1 - a_1 \beta_1'} \end{aligned} \right\} \quad . \quad . \quad . \quad (52)$$

25. The differential equation of the motion of the projectile in the gun, as stated by Sarrau, was given in paragraph 6.

$$(u + u_0) \frac{d^2u}{dt^2} + \theta \left(\frac{du}{dt} \right)^2 = f \frac{y}{M} \quad . \quad . \quad . \quad . \quad (53)$$

In the case arising when the charge is completely consumed in the bore of the gun, we may approximately determine the force of the powder f, by use of this last expression.

Denoting in (53) by y the weight of the products of combustion at the instant of time t, then, if the whole charge is consumed in the bore, we may substitute in the left hand member of the equation the value of the variables corresponding to the muzzle section of the bore; and in the right hand member $y = \tilde{\omega}$, where $\tilde{\omega}$ is the weight of the charge.

Multiplying both members of equation (53) by $M = \frac{p}{g}$, we find that

$$\frac{p}{g}\,\frac{d^2u}{dt^2} = P \cdot q,$$

where P is the pressure in atmospheres, and q the pressure of one atmosphere, expressed in units of weight, upon the base of the projectile and rifling.

Upon deducing (53) it was stated that $\frac{p}{2g}\left(\frac{du}{dt}\right)^2$ represented* the energy of the projectile in imparted accelerating and rotating impulses and the work of the powder gases expended in overcoming the friction of the rotating band of the projectile over the rifling and in overcoming other obstacles.

We may, therefore, present equation (53) in the following form,

$$(u + u_0)\,Pq + \theta(1 + \nu)\,\frac{pv^2}{g} = fy \quad . \quad . \quad . \quad . \quad . \quad (54)$$

Substituting in this last equation $u = U$, the length of the travel of the projectile in the bore, $v = V$, the initial velocity; $P = P_1$, the muzzle pressure, and $y = \tilde{\omega}$, the weight of the charge, we have

$$f = (U + u_0)\,\frac{P_1 q}{\tilde{\omega}} + \theta(1 + \nu)\,\frac{pV^2}{g\tilde{\omega}} \quad . \quad . \quad . \quad . \quad (55)$$

Assuming $\theta = 0.2$ for smokeless powder, we may employ the last equation for calculating the force of the powder f with data obtained from firings of varieties of smokeless powders experimented with.

* The factor $\frac{1}{2}$ is included in the coefficient θ.

The results of these calculations are embodied in the following table:

Variety of Smokeless Powder.	Designation of gun in which powder was tried.	Weight of Projectile.	Weight of Charge.	Initial Velocity	Muzzle Pressure.	Force of Powder f.
		lbs.	lbs.	ft. sec.	atm.	atm. per sq. cm.
Okhta	Light gun	$16\frac{3}{4}$	$1\frac{65}{96}$	1673	329	10,700
Okhta	4.2 in.	$39\frac{3}{4}$	$4\frac{60}{96}$	1796	334	10,900
Okhta especially prepared for the 4.2-gun	4.2 in.	$39\frac{3}{4}$	$5\frac{72}{96}$	1962	467	11,500
Okhta prepared from naval gun cotton	4.2 in.	$39\frac{3}{4}$	$6\frac{45}{96}$	1960	539	11,000
French	4.2 in.	$39\frac{3}{4}$	$5\frac{33}{96}$	1845	380	10,400
Rottweil nitro-glycerine	4.2 in.	$39\frac{3}{4}$	$4\frac{15}{96}$	1846	396	12,800

It is evident from this table that the force, f, of gun-cotton powders is about 11,000 atmospheres per square centimeter, and of Rottweil nitro-glycerine powder about 13,000 per square centimeter.

Using formula (45) to calculate the force of coarse grained powder from data obtained from firings of the 4.2-inch gun, and putting $\theta = 0.6$ according to the results of Sarrau's investigations (p. 28, Nouvelles Recherches sur les Effets de la Poudre), we find

$$f = 2466 \text{ atm. per sq. cm.}$$

This result is close to that experimentally obtained by Noble for the varieties of saltpetre-sulphur-charcoal powders examined by him.

26. Having ascertained the force of the powder, f, we may find from formula (54) the weight of the products of combustion of the

charge for various sections along the bore, by substituting in it the values of P and v corresponding to these sections.

Dividing both members of the equation by $f\tilde{\omega}$, we obtain an expression for determining the portions of the charge consumed in various sections of the bore. We have

$$\frac{y}{\tilde{\omega}} = (u + u_0)\frac{Pq}{f\tilde{\omega}} + \theta(1 + v)\frac{pv^2}{g\tilde{\omega}f}. \quad . \quad . \quad . \quad (56)$$

Applying this formula to the calculation of $\frac{y}{\tilde{\omega}}$ from the results of firings of the 4 lbs. $3\frac{3}{4}$ oz. of Okhta smokeless powder with projectile of $39\frac{3}{4}$ lbs. weight from the 4.2-inch gun, we obtain the results contained in the following table:

Distance of Section of Bore from Base of Bore.	The Relation $\frac{y}{\tilde{\omega}}$.
in.	
16.9	0.
20.9	0.40
25.0	0.56
29.0	0.69
33.6	0.79
42.0	0.90
53.2	0.96
61.8	0.98
85.4	1.00
127.4	1.00
136.0	1.00

This table shows that when the maximum pressure has been developed in the bore, that is, when the projectile has traversed a distance of about three calibres, two-thirds of the charge has been consumed; and that after it has advanced eleven calibres, nearly the whole charge has been consumed.

TABLE I.*

Results of Firing the Light Gun (3.425-in. Cal.)

KIND OF POWDER.			Smokeless Okhta Factory.		Smokeless French.		Smokeless Schlüsselburg Factory.	
Weight of charge			1 lb. 11 oz. ($1\frac{85}{96}$ lbs.).		1 lb. 14 oz. ($1\frac{85}{96}$ lbs.).		2 lbs. 2 oz. ($2\frac{13}{96}$ lbs.).	
Thickness of strip or riband			.034 in.		.030 in.		.036 in.	
Initial velocity in ft.-sec.			1673		1686		1691	
			Exper'l.	Calc'd.	Exper'l.	Calc'd.	Exper'l.	Calc'd.
Pressure in atmospheres.	At base of bore		1530		1595		1409	
	Distance from base of bore.	4.5 in.	1474		1437		1315	
		12.0 in.	1490		1536		1340	
		19.0 in.	1588	1660	1595	1582	1391	1414
		24.5 in.	1489	1443	1353	1381	1371	1318
		34.5 in.	1063	940	940	889	1029	980
		48.0 in.	441	553	488	537	625	676
		66.5 in.	307	310	339	305	442	450
Calculated pressures determined by the equation $P=\frac{a}{x^{1.4}}\left(1+\frac{b}{x}-\frac{c}{x^2}\right)$.								
	log a		3.7971		3.8670		4.4868	
	log b		1.7804		1.6682		$\bar{1}$.6959	
	log c		2.4494		2.3444		1.2601	
x equals the distance from the base of bore plus 2.36 in., and expressed in calibres.								

Length of powder chamber, 9.35 in.; whole length of bore, 73.4 in.; weight of projectile, 16.75 lbs.

*In all these tables the "registered" initial velocities and pressures represent mean values averaged from the results afforded by five shots. It may be noted that the differences between individual records were insignificant.

TABLE II.

Results of Firing the 4.2-in. Gun.

KIND OF POWDER.		Smokeless Okhta Factory.					
Thickness of strips or dimensions of grain.		.035 inches.					
Weight of charge		4 lbs. 10 oz. ($4\frac{80}{96}$ lbs.).		4 lbs. $0\frac{9}{16}$ oz. ($4\frac{9}{96}$ lbs.).		3 lbs. $7\frac{1}{2}$ oz. ($3\frac{44}{96}$ lbs.).	
Weight of projectile		39.75 lbs.		39.75 lbs.		39.75 lbs.	
Initial velocity in ft. sec.		1796		1657		1494	
		Exper'l.	Calc'd.	Exper'l.	Calc'd.	Exper'l.	Calc'd.
Pressures in atmospheres.	At base of bore	1722		1390		1045	
	At distance from base of bore. 8.4 in.	1684		1348		1022	
	At distance from base of bore. 16.8 in.	1657		1349		1017	
	At distance from base of bore. 21.0 in.	1650		1321		1009	
	At distance from base of bore. 25.2 in.	1675		1325		1004	
	At distance from base of bore. 29.0 in.	1693	1742	1376		1025	
	At distance from base of bore. 33.6 in.	1658	1673	1391	1413	1050	1057
	At distance from base of bore. 42.0 in.	1490	1416	1280	1284	960	975
	At distance from base of bore. 53.2 in.	1154	1095	1011	1018	827	800
	At distance from base of bore. 61.8 in.	872	904	814	844	732	681
	At distance from base of bore. 85.4 in.	509	573	453	529	351	457
	At distance from base of bore. 127.4 in.	323	309	343	274	311	261
Calculated pressures determined by the equation $P=\frac{a}{x^{1.4}}\left(1+\frac{b}{x}-\frac{c}{x^2}\right)$,							
	$\log a$	4.4220		4.2392		4.4395	
	$\log b$	1.3235		1.6403		1.0208	
	$\log c$	2.1931		2.5232		2.0370	
x equals the distance from base of bore plus 6.68 inches, and expressed in calibres.							

Length of powder chamber, 16.9 in.; full length of bore, 136 in.

TABLE II—(Continued).

Results of Firing the 4.2-in. Gun.

Smokeless Okhta Factory.				Smokeless manufactured at the Okhta Factory from Naval Gun Cotton.		Smokeless French.		Smokeless Köln Rottweil Factory.	
.035 inches.		.0425 in.		.044 in.		.032 in.		Cubical, edge of cube = 0.14 in.	
4 lbs. 10 oz. (4$\frac{10}{16}$ lbs.)		4 lbs. 10 oz. (4$\frac{10}{16}$ lbs.)		5$\frac{7}{16}$ lbs.		6 lbs. 7$\frac{1}{2}$ oz. (6$\frac{8}{16}$ lbs.)		5 lbs. 5$\frac{1}{2}$ oz. (5$\frac{33}{64}$ lbs.)		4 lbs. 2$\frac{1}{2}$ oz. (4$\frac{15}{16}$ lbs.	
35 lbs.		30.5 lbs.		39.75 lbs.		39.75 lbs.		39.75 lbs.		39.75 lbs.	
1862		1957		1962		1960		1845		1846	
Experimental.	Calculated.	Experimental.	Calculated.	Experimental.	Calculated.	Experimental.	Calculated	Experimental.	Calculated.	Experimental.	Calculated.
1536		1389		1794		1716		1731		1764	
1494		1354		1703		1642		1636		1670	
1490		1325		1685		1617		1607		1665	
1469		1310		1704		1608		1646		1685	
1461		1295		1675		1601		1692		1740	1759
1465		1303		1696		1622		1687	1727	1602	1690
1495	1536	1322	1377	1709	1709	1648	1635	1643	1679	1581	1589
1407	1401	1238	1243	1540	1598	1482	1544	1488	1436	1365	1344
1148	1119	1034	1022	1400	1349	1383	1346	1216	1140	1141	1065
999	933	944	871	1256	1176	1244	1199	968	960	893	903
524	593	530	546	743	829	837	888	591	637	551	614
313	315	318	336	Not Reg'd	504	Not Reg'd.	570	331	364	328	363
4.3629		4.5571		4.8196		4.9359		4.6020		4.6604	
1.5087		0.9844		$\bar{1}$.9140		0.6037*		0.8998		0.2462	
2.4089		2.0134		1.6378		0.8228		1.8884		1.5207	

*For this case the coefficient b became subtractive.

TABLE III.

Results of Firing the Light Gun (3.42-in.).

KIND OF POWDER.			COARSE GRAINED.	SMOKELESS POWDER.				
				Okhta.	Kazan.		Schlüsselburg.	Noble Nitro-glyc.
Thickness of strips or dimension of grain.			0.3 in.	.034 in.	.028 in.		.036 in.	Edge of cube =0.118″.
Weight of charge			$3\frac{49}{56}$ lbs.	$1\frac{49}{56}$ lbs.	$1\frac{79}{56}$ lbs.	$1\frac{45}{56}$ lbs.	$1\frac{78}{56}$ lbs.	$1\frac{72}{56}$ lbs.
Initial velocity in ft.-sec			1439	1463	1671	1474	1475	1752
Pressure in atmospheres.	At base of bore		1563	990	1557	1057	986	1592
	At distance from base of bore.	4.5 in.	1389	941	1472	972	959	1422
		12.0 in.	1459	967	1490	978	941	1537
		19.0 in.	1258	980	1575	1058	992	1555
		24.5 in.	1077	962	1430	1016	906	1327
		34.5 in.	585	735	825	710	742	1065
		48.0 in.	<300	336	441	335	443	458
		66.5 in.	<300	319	323	325	370	373

Weight of projectile, 16.75 lbs.; length of powder chamber, 9.35 in.; full length of bore, 73.4 in.

TABLE IV.

Results of Firing the 4.2-in. Gun.

KIND OF POWDER.			COARSE GRAIN'D	SMOKELESS POWDER.					
				Okhta.		Okhta made from naval gun-cotton.	French.	Rottweil.	
Thickness of strips or dimensions of grain.			0.3 in.	.035 in.	.0425in.	.044 in.	.032in.	Cubical Edge of cube =0.14″	
Weight of charge			8 lbs.	$4\frac{47}{56}$ lbs.	$3\frac{83}{56}$ lbs.	$3\frac{99}{56}$ lbs.	$4\frac{81}{56}$ lbs.	4 lbs.	3 lbs.
Initial velocity in ft.-sec.			1455	1802	1681	1495	1488	1484	1485
Length of powder chamber, inches			16.9	14.9	12.4	16.9	16.9	16.9	16.9
Pressure in atmospheres.	At base of bore		1730	1719	1529	890	895	1037	1061
	Distance from base of bore.	8.4 in.	1577	1680	1490	860	880	959	995
		16.8 in.	1644	1652	1476	846	859	947	995
		21.0 in.	1805	1659	1481	839	859	950	995
		25.2 in.	1366	1684	1487	864	861	964	1005
		29.0 in.	1338	1746	1543	867	863	953	1011
		33.6 in.	1101	1666	1430	877	862	941	955
		42.0 in.	767	1459	1276	833	831	843	853
		53.2 in.	603	1036	923	751	750	788	750
		61.8 in.	481	840	754	671	690	675	633
		85.4 in.	330	503	407	464	509	394	346
		127.4 in.	<300	Not recorded.	Not recorded.	Not recorded.	Not recorded.	306	<300

Weight of projectile, 39.75 lbs.; whole length of bore, 136 in.

TABLE V.

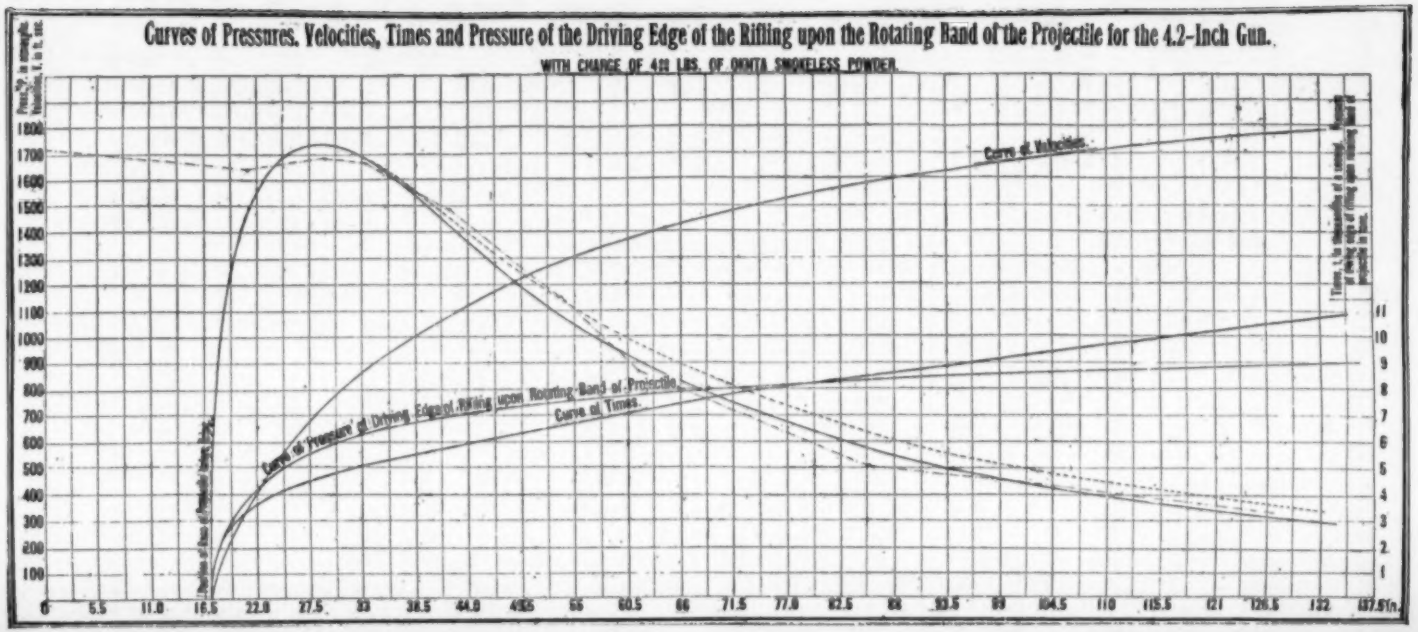
Results of Firing 6-in. Gun.

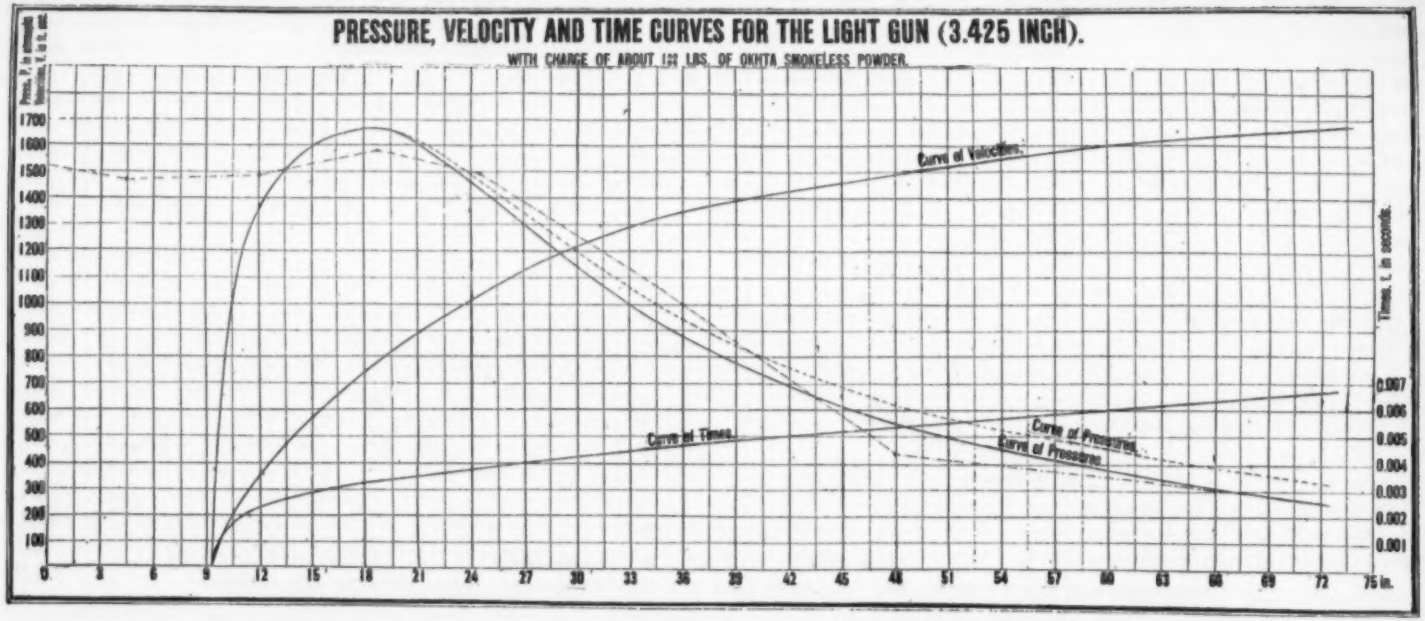
KIND OF POWDER.			Prismatic, density 1.69	Smokeless Powder.					
				Okhta.			French.	Rottweil.	
Thickness of riband or dimensions of grain.			Height of prism 1 in.	0.053 in.			0.039 in.	Edge of cube 0.3 in.	
Weight of charge			21 lbs.	12 lbs.	10.4 lbs.	9 lbs.	11¼ lbs.	13⅝ lbs.	11¼ lbs.
Initial velocity in ft.-sec.			1525	1835	1635	1469	1783	1766	1502
Pressure in atmospheres.	At base of bore.		1886	1750	1333	1011	1864	1592	1060
	Distance from base of bore.	10.4 in.	1788	1687	1317	963	1800	1557	1026
		23.7 in.	1808	1686	1295	967	1763	1549	1022
		26.0 in.	1742	1639	1306	969	1700	1529	952
		31.8 in.	1980	1649	1303	958	1876	1592	1006
		37.3 in.	1617	1734	1373	987	1850	1623	1056
		42.8 in.	1402	1798	1379	995	1885	1670	1193
		48.2 in.	1187	1693	1273	958	1714	1464	975
		79.6 in.	581	951	810	670	832	928	686
		110.0 in.	327	461	397	341	392	490	407

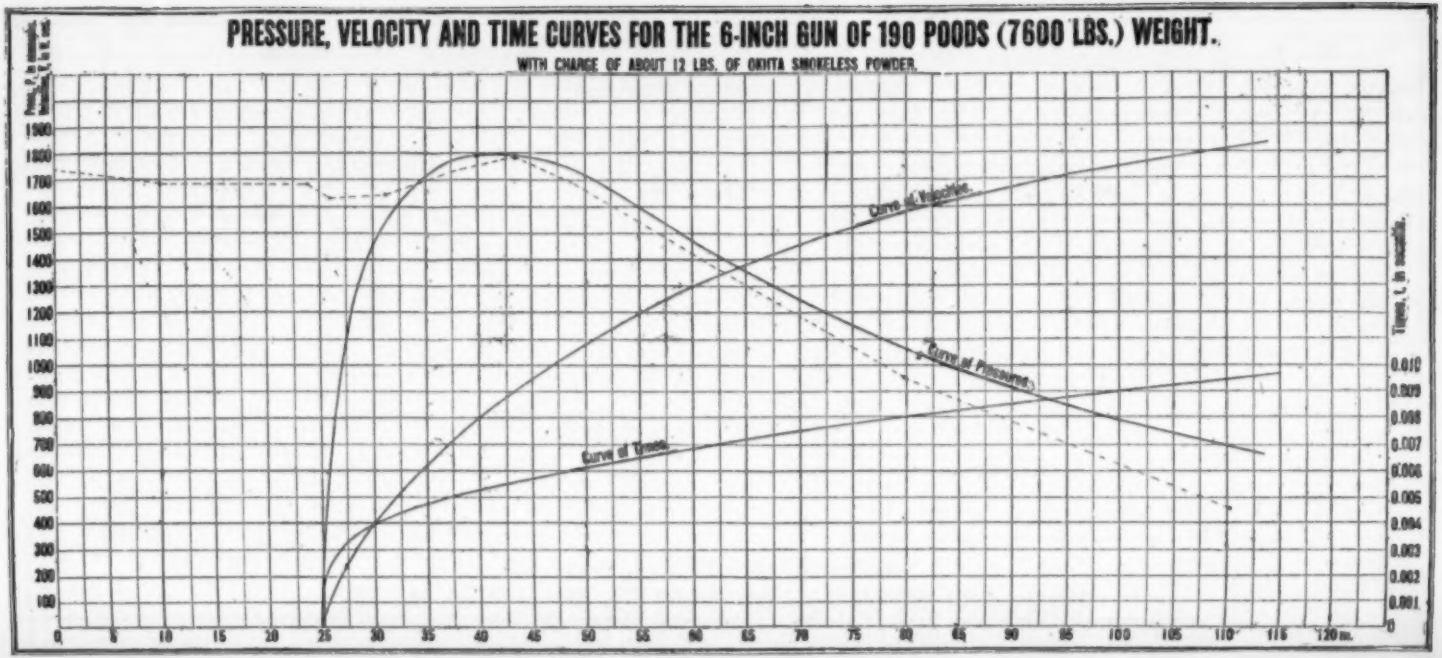
Weight of projectile, 81¼ lbs.; Length of powder chamber, 24.9 in.; whole length of bore, 114 in.

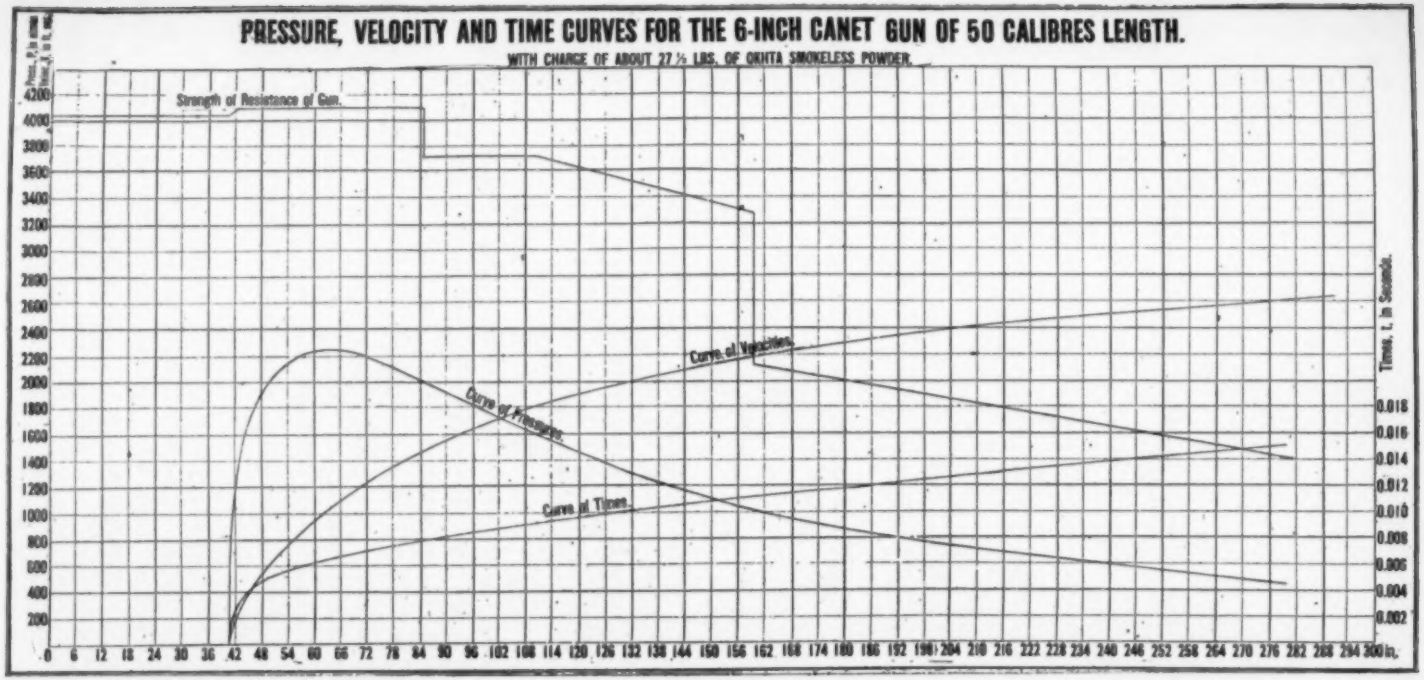
TABLE VI.

Designation of Gun.	Kind of Smokeless Powder.	Weight of Charge.	Weight of Projectile.	Length of Powder Chamber.	Breech Pressure.		Initial Velocity.	
					Registered.	Calculated.	Registered.	Calculated.
Showing relation of pressure and initial velocity to weight of charge.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
Light gun (3.42 in.)	Okhta ...	$1\frac{65}{96}$ lbs.	$16\frac{3}{4}$ lbs.	9.35	1530		1673	
		$1\frac{40}{96}$ lbs.			990	1093	1463	1473
	Kazan....	$1\frac{70}{96}$ lbs.			1557		1671	
		$1\frac{45}{96}$ lbs.			1057	1125	1474	1479
	Schlüssel-burg.	$2\frac{12}{96}$ lbs.			1409		1691	
		$1\frac{78}{96}$ lbs.			986	1027	1475	1502
4.2 inch gun.	Okhta, thickness of strips 0.035 in.	$4\frac{69}{96}$ lbs.	$39\frac{3}{4}$ lbs.	16.9	1722		1796	
		$4\frac{4}{96}$ lbs.			1390	1311	1657	1622
		$3\frac{44}{96}$ lbs.			1045	962	1494	1443
	Okhta, thickness of strips 0.0425 in.	$5\frac{3}{4}$ lbs.			1794		1962	
		$3\frac{89}{96}$ lbs.			890	842	1495	1478
	Okhta made from naval gun cotton.	$6\frac{45}{96}$ lbs.			1716		1960	
		$4\frac{51}{96}$ lbs.			895	841	1488	1501
	French.	$5\frac{33}{96}$ lbs.			1731		1845	
		4 lbs.			1037	972	1484	1486
	Rottweil.	$4\frac{13}{96}$ lbs.			1764		1846	
		3 lbs.			1061	917	1485	1444
6-in. gun of 190 poods (7600 lbs.) weight.	Okhta	12 lbs.	$81\frac{1}{4}$ lbs.	24.9	1750		1835	
		$10\frac{47}{96}$ lbs.			1333	1324	1635	1653
		9 lbs.			1011	984	1469	1479
	Rottweil.	$13\frac{3}{4}$ lbs.			1592		1766	
		$11\frac{1}{4}$ lbs.			1060	1067	1502	1520
Showing relation of pressure and initial velocity to weight of projectile.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
4.2 inch gun.	Okhta	$4\frac{69}{96}$ lbs.	$39\frac{3}{4}$ lbs.	16.9	1722		1796	
			35 lbs.		1536	1565	1862	1869
			$30\frac{1}{2}$ lbs.		1389	1396	1957	1960
Showing relation of pressure and initial velocity to length of powder chamber.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
4.2 inch gun.	Okhta	$4\frac{47}{96}$ lbs.	$39\frac{3}{4}$ lbs.	14.9	1719		1802	
		$3\frac{82}{96}$ lbs.		12.4	1529	1519	1681	1682


Curves of Pressures, Velocities, Times and Pressure of the Driving Edge of the Rifling upon the Rotating Band of the Projectile for the 4.2-Inch Gun.
WITH CHARGE OF 421 LBS. OF DINITA SMOKELESS POWDER
Curve of Velocities.
Curve of Times.
Curve of "Pressure" of Driving Edge of Rifling upon Rotating Band of Projectile.
Position of Face of Projectile before Firing.
Pressures in tons per sq. in. Velocities, f. s. & t. sec.
Times, t. in thousandths of a second, of passage of Driving Edge of Rifling upon Rotating Band of Projectile in Bore.
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
5.5
11.0
16.5
22.0
27.5
33
38.5
44.0
49.5
55
60.5
66
71.5
77.0
82.5
88
93.5
99
104.5
110
115.5
121
126.5
132
137.5 in.
11
10
9
8
7
6
5
4
3
2
1


PRESSURE, VELOCITY AND TIME CURVES FOR THE LIGHT GUN (3.425 INCH).
WITH CHARGE OF ABOUT 1½ LBS. OF OKHTA SMOKELESS POWDER.
Press. P. in pounds per square inch, Velocities, V. in f. s. per sec.
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
Curve of Velocities.
Curve of Times.
Curve of Pressures.
Curve of Pressures.
Times, t. in seconds.
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
57
60
63
66
69
72
75 in.


PRESSURE, VELOCITY AND TIME CURVES FOR THE 6-INCH GUN OF 190 POODS (7600 LBS.) WEIGHT.
WITH CHARGE OF ABOUT 12 LBS. OF OKHTA SMOKELESS POWDER.
Curve of Velocities
Curve of Pressures
Curve of Times
Times, t, in seconds.
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 in.


PRESSURE, VELOCITY AND TIME CURVES FOR THE 6-INCH CANET GUN OF 50 CALIBRES LENGTH.
WITH CHARGE OF ABOUT 27½ LBS. OF OKHTA SMOKELESS POWDER.
Strength of Resistance of Gun.
Curve of Velocities.
Curve of Pressures.
Curve of Times.
Times, t, in Seconds.
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120 126 132 138 144 150 156 162 168 174 180 186 192 198 204 210 216 222 228 234 240 246 252 258 264 270 276 282 288 294 300 in.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE DISAPPEARING GUN AFLOAT.

By Assistant Naval Constructor Richmond Pearson Hobson, U. S. N.

The following paper is the substance of a report made last April on a Model with Disappearing Turrets submitted to the Navy Department by G. W. Van Hoose, Esq.

The idea of the possibility of interest in the publication of the report was first suggested by the bearing that the portion treating of the relative protection of the different elements of efficiency has on the method of estimating naval strength, of estimating the power or value of a vessel of war, as found in the author's paper on the Study of Coming War and in the discussion of the method.

The idea was further suggested by the interest evinced by officers in the subject of the relative exposure of the parts of a vessel, the probability of a particular part being hit in action by the projectiles of different calibers, and the effects of such hits on the efficiency of the vessel.

Some ideas found to be held currently are somewhat at variance with the conclusions arrived at, and some are unformulated, evidently from lack of data, and it was decided that these points, which are of such vital interest both for design, particularly in the distribution of armor, and for directing an engagement, should be further investigated and expanded into a paper which would omit the parts of the report of minor interest. But the pressure of current duties has prevented this investigation and offers little prospect for the near future.

In consequence, it has been decided to offer the paper for publication as it stands. Having been made thus only as incident to, or involved in the investigation of a particular case, the treatment of the broad subject alluded to, while comprehensive in scope, is only suggestive, not exhaustive in its nature.

I.

The model was presented by Mr. Van Hoose in person without any written statement, explanation, or description whatsoever, with the verbal request to the effect that the dispositions embodied and the principles and ideas illustrated be examined as to their utility for adoption on vessels of war.

In order to approximate to the nature of the request and to the extent of the claims, questions were put to and answered by the applicant as to the features, strategical and tactical, of the vessel represented by the model.

These questions and answers are given below. The answers and the explanation of the model demonstrated the fact that the pervading idea is the use of the disappearing principle in such a form that, combined with a flush upper deck, it will permit fire across the above deck positions when the guns are below deck, thus reducing the obstruction and increasing the effective angles of fire.

The method employed by the applicant to realize the ideas of the system is indicated only in outline on the model and was supplemented later by a sketch from patent specifications showing a modified form of barbette and a sectional elevation without dimensions, scantlings, details, or description of any kind. In his verbal description of the method, the applicant explained only the ideas adopted and expressed the desire that the details as found be not entered as part of the examination, as their purpose was only that of illustration. In consequence, a critical examination of the details of the method is not entered into at length, though it is shown that on the practical efficiency of the method and the perfections of the details will depend the entire value of the system.

In order to arrive at conclusions as to the utility of the disappearing principle in the form in which it appears, the features are examined as follows, namely :—

1. The sacrifice of the superstructure, entailed by the system.

2. The extent of the advantage gained in increase of power of the main battery and in increase of protection to guns.

In investigating the increase of protection to guns the question of the advantage to be gained by *any* increase is first considered,

the method adopted being the investigation in usual systems of the relative protection of turret guns and of the other elements of efficiency, adequate protection to each element being the object sought. Then the amount of the increase realized by the system proposed over usual systems is considered.

3. Remarks on certain features inherent in the system and on certain features of the methods proposed by the applicant.

4. A summary comparison of the system in an ameliorated form with systems employed abroad on board ship.

5. Summations, conclusions.

II.

INTERROGATORIES.

GENERAL STRATEGICAL AND TACTICAL FEATURES.

Q. Speed?

A. Not specified.

Q. Endurance at a given speed?

A. Not specified.

Q. Type of vessel?

A. Seagoing battleship.

Q. Designed for engaging in squadron or in duel?

A. For both; duel preferred.

Q. Main object?

A. To crush enemy by battery power.

Q. Best position for engaging—end on, on quarter, or abeam?

A. Any position; end on preferred.

Q. Best distance for engaging—long range, moderate range, or close quarters?

A. All three; moderate range preferred.

SUMMARY DESCRIPTION.

Q. Principal dimensions?

A. Not specified.

Q. Displacement?

A. Not specified; supposed to be not less than 12,000 tons.

Q. Condition of stability and steadiness of gun platform?

A. Not specified.

Q. Apportionment of weight?

A. Not specified.

OFFENSIVE POWER.

1. *Artillery.*

Q. Heavy artillery?

A. Four 10″ B. L. R. or larger caliber, in two armored cages, disappearing after firing to loading positions within two barbettes situated in center line of vessel, one forward and one aft.

Eight 8″ B. L. R. or larger calibre, in four armored cages, disappearing after firing to loading positions within four barbettes situated two on each beam in waist.

Q. Medium caliber artillery?

A. Not specified; preferred to be developed as much as possible. The pieces—8 on the gun deck, 4 on bridge deck, 1 on each side of the cages of the heavy guns in center line and 1 between the two guns of each waist barbette—are all of undefined caliber.

Q. Light artillery?

A. Not specified other than four Gatling guns in two military tops of two masts that are raised and lowered, the top being housed below the upper deck and the guns firing from a position above the upper deck as well as in the raised position.

Q. Angle of fire.—For successive fire?

A. All heavy guns have an arc of practically 360 degrees.

Q. For volley fire?

A. In two volleys of short interval of separation all guns can bear in all directions. End on, the first volley brings to bear two 10″ and four 8″; the second volley the same; quartering fire, one volley brings whole battery; beam fire, the first volley brings to bear four 10″ and four 8″, the second volley brings to bear four 8″.

Q. Ammunition supply?

A. Nothing specified.

2. *Torpedoes.*

Q. Number of submarine discharging tubes?

A. Not specified.

Q. Number of over-water discharging tubes?

A. Not specified.

3. *Ram.*

Q. Ram bow?

A. Affirmative. Nothing further specified.

DEFENSIVE POWER.

Protection by Armor.

Q. For hull and stability by side armor?

A. Nothing specified.

Q. For hull and stability by deck armor?

A. Nothing specified, although it would have an armored bulkhead forward of forward barbette.

Q. For artillery and personnel?

A. For heavy guns, armored cages with heavy armor on their sloping faces and lighter armor on the sides, disappearing for the loading position, guns and cages, into fixed barbettes of heavy armor. Nothing further specified.

Q. Protection by subdivision?

A. Nothing specified.

Q. Protection by coal?

A. Nothing specified.

Q. Protection by empty spaces?

A. Nothing specified.

Q. Protection by nets?

A. Nothing specified.

STRUCTURAL FEATURES.

Construction.

Q. Form of lines?

A. Nothing specified.

Hull.

Q. Internal arrangements, position of boilers, engines, coal bunkers, ammunition rooms, quarters, berthing, etc., etc.?

A. Nothing specified.

Q. Upper works?

A. There are to be no upper works, other than a bridge and boat cradles built on three or more skid beams.

Q. Ventilation, drainage, lighting, etc., etc.?

A. Nothing specified.

Hull Fittings.

Q. Rudder, steering gear, anchor gear, boat gear, torpedo net gear, etc., etc.?

A. Nothing specified.

Q. Masts?

A. Two or more military masts to be raised from housed positions below the upper deck to fighting positions by appliances, using any sort of power, and to be secured in the fighting positions by stays and guys. Nothing further specified.

Propulsion.

Q. Indicated horse power?

A. Not specified.

Engines.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified.

Boilers.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified.

Screws.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified. The model has three four-bladed screws.

Summing up the answers, the applicant intends the model to represent a seagoing battleship of large displacement. The battery of heavy guns is to be highly developed, their effective power is to be increased by increasing largely the arc of fire, to which end all upper works are sacrificed, and the guns are made to be able to disappear within barbettes below the upper deck after firing so as to leave the field unobstructed for other guns. The military masts are also made to disappear below the upper deck. In this manner, by firing in turn, each gun can be brought to bear over the whole horizon, and the barbettes are so grouped that, for certain points on the bows and quarters, all guns can be brought to bear simultaneously.

While increasing the arc of fire of other guns by disappearing below the upper deck, the heavy guns are intended to increase their own protection by lowering into barbettes, reducing the time of exposure to direct fire to the interval necessary for training and sighting and during this interval protection of the breech against rapid-fire guns is afforded by cage armor, with the increased thickness of armor on the front sloping face.

The general disposition by which these objects are represented to be accomplished is shown in sketches of the model Figs. 1, 2, 3. The ratio of beam to length is 5 to 1; the ratio of beam to draught 2.8 to 1, the ratio of freeboard to draught 1 to 1.485. The same ratios for the Iowa are 5 to 1, 3 to 1, and 1 to 1.354, respectively. The proportions are good; and as a piece of workmanship the model shows a skill and ingenuity remarkable under the circumstances under which it was made.

The features which render the carrying out of the model as it stands impracticable if not impossible—such as the disposition of rapid-fire guns along with heavy guns—will not be discussed, as it is evident from the answers above, the applicant's object in making and submitting the model was not to offer a model for a design, but to offer simply an illustration, in concrete form, of a method of increasing the effective power and efficiency of the main battery, by increasing the angle of fire and the mean security of the heavy guns.

To this end, two distinct dispositions are employed: First, the disposition of a flush upper deck without any superstructure or upper works of any consequence that would obstruct the angle of fire; second, the use of disappearing mounts, by which the heavy guns, after firing, can be made to sink into armored barbettes below the level of the upper deck, leaving the field unobstructed for the fire of other guns and realizing an additional security during the period of loading.

Upper works have been sacrificed to arcs of fire in degrees varying from the least to the greatest in war vessels of nearly every maritime power, while disappearing guns have been mounted in five vessels, four Russian and one British. Sketches Figs. 4 and 5 show the disposition on the three recent Russian battleships, the Catharine the Second, the Tchesme, and the Sinope, launched in 1886 and 1887. Fig. 6 shows the disposition on the Russian circular coast-defence vessel, the Vice Admiral Popoff, launched in 1875. Figs. 7 and 8 show the disposition on the British battleship, the Temeraire, completed in 1877. On the Catharine the Second class, the six 12″ guns are mounted in a single armored redoubt. On the Temeraire the two barbettes are situated at the extremities with upper works intervening, not shown on the profile sketch but indicated on the plan, which

allows the disappearing gun to realize only the moderate angle of fire of 240°. On the Vice Admiral Popoff the two disappearing guns are mounted side by side in one position. In each case the guns are raised only high enough to clear the top of the encircling armor. In none of the cases is the disposition made for firing the heavy guns over the barbettes, redoubt, or pit, into which the guns sink. The only objects sought in adopting the disappearing principle are the increase of protection and the saving of weight.

The model represents, as far as extensive research has disclosed, the first disposition where the disappearing principle is designed to clear the field of guns during the process of loading in such a way as to permit unobstructed fire across the space occupied by them in the firing position, the deck being cleared of other obstructions, to realize thus the double purpose of increasing the effective angles of fire of the heavy guns, and, at the same time, of increasing their protection.

III.

In order to realize the advantage of this novel feature, it is first necessary to clear the deck of obstructions. The superstructure must be abandoned with the mounts it furnishes within and on top for pieces of the secondary battery and housed space available for quarters, berthing, etc. Incident to this measure there would be a gain of weight and an increase of stability, depending in amount on the weight and position of the objects removed. It would further reduce the area of the target offered by an amount depending on the dimensions of the superstructure.

On the other hand, it would *increase* the period of roll and consequent steadiness of gun platform by an amount depending on the weight and position of the objects removed. It would reduce the secondary battery by an amount depending on the number and importance of the pieces whose mounts were swept away. In many cases, the loss of power of secondary battery would be so great as to be altogether inadmissible, not only because of the heavy reduction in power of offense against unarmored and lightly armored vessels and parts of armored vessels, but also because of the serious reduction of power of defense against the attack of torpedoes, now so widely carried by unprotected but swift vessels.

MODEL SUBMITTED BY C. W. VAN HOOSE, ESQ.

FIG. 1 OUTBOARD PROFILE,
TURRETS AND MASTS IN FIRING POSITION.

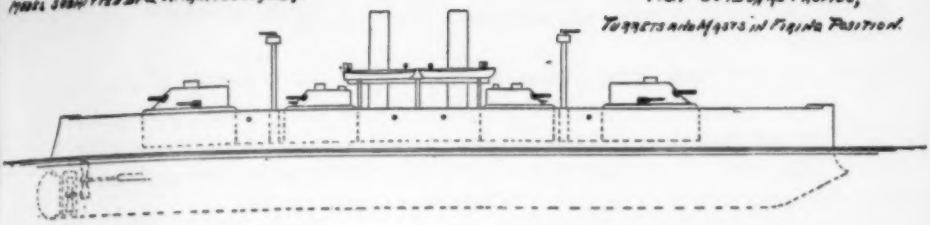
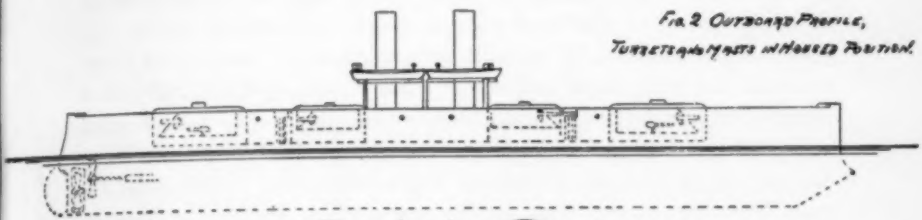


FIG. 2 OUTBOARD PROFILE,
TURRETS AND MASTS IN HOOKED POSITION.



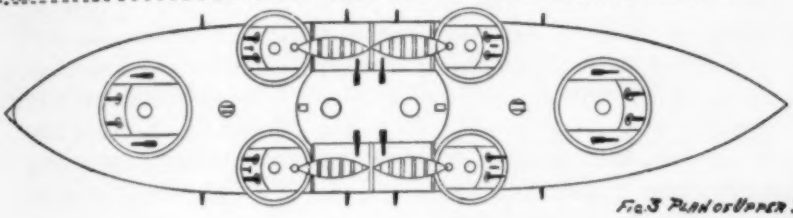


FIG. 3 PLAN OF UPPER DECK

CATHERINE II

FIG. 4

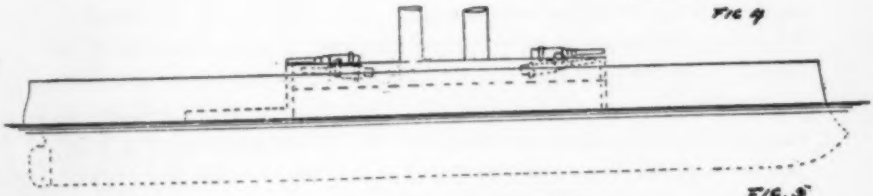


FIG. 5

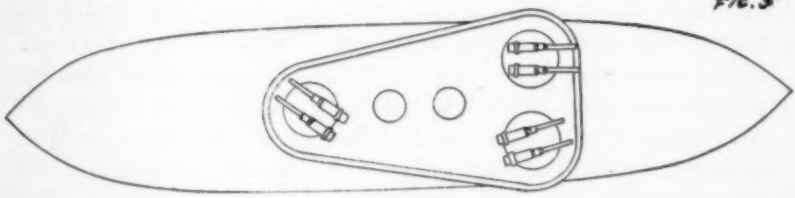


FIG. 7 TEMERAIRE.

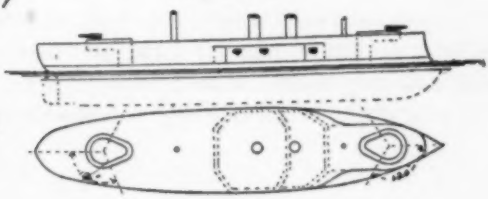


FIG. 8

In the case of the Indiana, the loss would comprise all four of the 6″, and fourteen out of eighteen of the 6-pdrs., practically an annihilation of the secondary battery, which would reduce the rôle of the battleship to that of a coast-defense vessel unfitted to approach within radius of a hostile torpedo flotilla.

The secondary battery, being indispensable and being swept from the level of the heavy guns, must find mounts below this level, or else above it on objects not swept away, which can carry mounts for only light calibers. This would lead naturally to a developed gun deck battery which would necessitate a deck more of freeboard, increasing thereby the hull weight and the size of target offered and necessitating higher barbettes which must extend from the upper deck to the armor deck, increasing thus the weight of armor. The result would either be a serious decrease of weight and consequent reduction of efficiency of other important elements, or else a considerable increase in displacement with consequent increase of cost. It would change the Indiana into an Iowa with her upper deck extended to the stern, permitting an increase of power of secondary battery and necessitating an increase of her displacement and cost.

There might be a condition in which the necessity of a gun deck and the incident advantages just cited could be avoided. The guns of the secondary battery, instead of being lowered to the distance of the gun deck, could be left still to fire over the upper deck, if they were within light turrets similar to those adopted on recent French battleships, the platforms of the turrets being below the level of the deck and the gun a short distance above this level. The rise of the heavy guns above the deck would have to be somewhat increased so that they could fire over these turrets without danger of injuring them from the blasts, measures being taken to prevent depression when firing in the line of the small turrets sufficient to hit them. Guns of lighter caliber swept away could be mounted higher on the bridge, which could be supported in a developed form with chart-house by smokestacks and masts. The boats whose cradles would be swept away with superstructure, could be carried on skid beams assembled and secured by bolts which, before action, would be unrigged and sent below, the boats being put overboard. The conning-tower would have to remain the sole obstruction, offering a conspicuous and exposed

Vice Admiral Popoff

Fig. 6

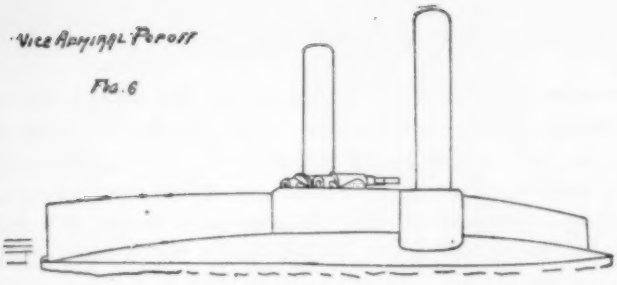
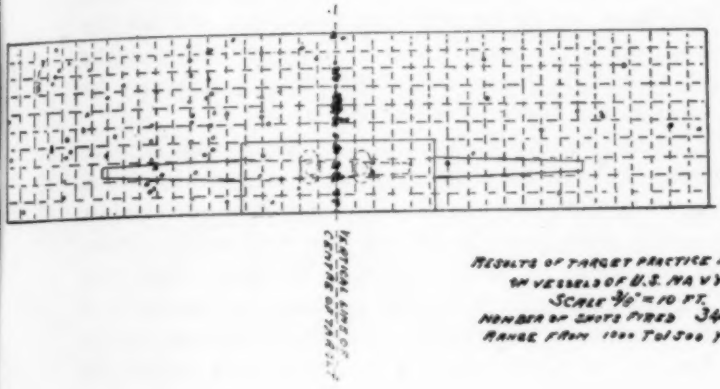


Fig. 4.



RESULTS OF TARGET PRACTICE FOR 6" BL.R
ON VESSELS OF U.S. NAVY
SCALE 1/2" = 10 FT.
NUMBER OF SHOTS FIRED 340
RANGE FROM 1000 TO 3000 YARDS

Fig 11

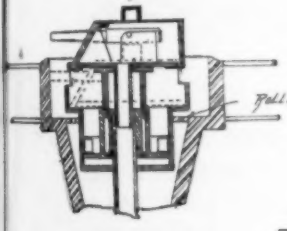


Fig 13

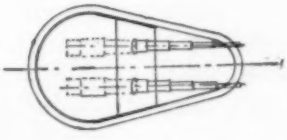


Fig 12.

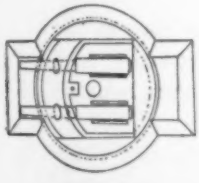
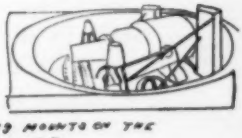


Fig. 16

Fig. 16.



Figs 16 & 16. System of Disappearing Mounts on the British Battle-Ship Temeraire.

Fig 11 Details.
System of disappearing carriage adopted by U.S. Navy Board 1886
Fig 13
Form of Breech-loading gun for disappearing mount

target, or else it would have to descend to the level of the small turrets just described, with the necessity of having a portion of the horizon cut off by the heavy guns while in the firing position. With the conning-tower placed well forward of the forward turret, with perhaps a second one aft, abaft the after turret, this disposition would incur but slight objection on this score, offering a better view than the usual disposition within the horizon of an engagement, a view obstructed only in the rear and then only intermittently by the heavy guns. A conning-tower consistent with this condition would be one that could rise and fall like the turrets; or, if not the conning-tower proper, an armored tube large enough to contain one or more men with an apparatus for communicating to the conning-tower proper.

Thus, for battleships, the disadvantages incident to the sacrifice of the superstructure and the removal of the objects of obstruction above the upper deck in order to have the deck flush and clear for the disappearing guns, though serious, are not, on the whole, without the possibility of partial remedy. In many cases they are not of serious consequence. This first measure, necessary to the realization of the advantages sought in increasing the effective angle of fire of the heavy guns, does not present insuperable obstacles.

For coast defense vessels, which have less need of a developed secondary battery, the disadvantages and difficulties are less serious than for battleships.

IV.

With a flush unobstructed deck, the minimum total angle of fire gained for each gun by the disappearing system proposed is the sum of the angles subtended by the turrets of other guns. As a matter of fact, a shot would never be allowed to be fired so that the circumference would pass tangent to a turret.

The absolute minimum of a gain would be the sum of the angles subtended by the turrets plus the angles subtended in each case by the caliber of the gun firing placed at a distance equal to the distance of the point of tangency from the gun.

Where the guns of the two turrets are on the same level it would not be safe to allow the projectiles to pass within the circle swept by the muzzles of the guns of the turrets in question. Assuming

Fig. 19.

Sketch of Disappearing Mount on the Russian Battle-Ship Catherine II "Tereza" and Cruiser

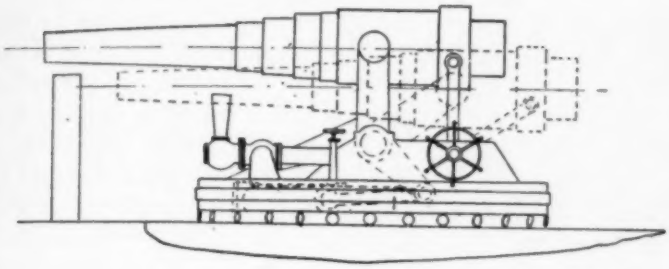


Fig 17

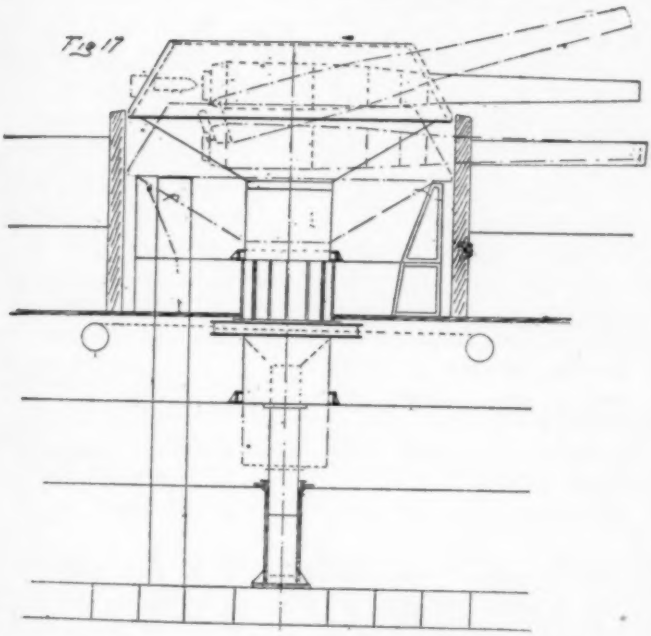
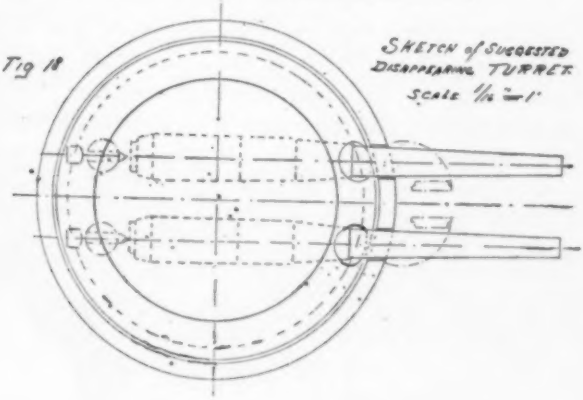


Fig 18

Sketch of Suggested Disappearing Turret

Scale 1/2 = 1'



that the gain is only the sum of the angles subtended by the turrets in the case of guns on different levels, the least favorable assumption, and that it is the sum of the angles subtended by the circles swept by the muzzles when the guns are on the same level, the total gain in usual cases would be large even with the best disposition of the turrets. On the Iowa, the sum of the angles subtended by turrets for the guns of a 12″ turret is about 35 degrees; the dead angle as now provided being about 90 degrees. The sum for the guns of an 8″ turret is about 95 degrees, the dead angle being 195 degrees. When the circles swept by the muzzles are taken instead of the turrets for the cases of guns on the same level, the sum becomes 90 degrees, the total dead angle, for the forward 12″ guns, and 165 degrees, $\frac{33}{39}$ of the dead angle, for all of the 8″ guns, the forward 12″ and all of the 8″ guns being on the same level, which indicates that in reality the presence of a superstructure would add but little to the dead angle.

The necessary gain in angle of fire for the Iowa, with her present position of guns, by the use of mounts disappearing as proposed, would thus be as follows:—

For the forward	12″ guns,	- - -	90 degrees
" " after	12″ "	- - -	55 "
Total for	12″ "	- - -	145 degrees
Mean gain		- - -	72½ "
For all the	8″ "	- - -	165 "

The effective gain would practically be in each case the dead angles, 90 degrees for the 12″ guns and 195 degrees for the 8″ guns. Assuming that the angles gained are of equal value with angles of the other bearings, that angle of fire is of uniform importance around the horizon, an assumption that will not be discussed, being of sufficient accuracy for the purpose of the present comparison, the proposed system would add practically ⅓ to the effective angle of the 12″ guns and practically double the angle of the 8″ guns. Take muzzle energy as the comparison between the two calibers. The four 12″ guns in a single round aggregate 4 × 26,000 ft. tons, equals 104,000 ft. tons, and the eight 8″ guns in a single round aggregate about 8 × 8000 ft. tons, equals 64,000 ft. tons. The relative amount of energy in a single

discharge is as 13 to 8. Taking one minute and a half as the interval between the rounds for the 8″, and 3 minutes as the interval for 12″ guns, then, in a given length of time, sufficiently long, the total muzzle energy generated by the two batteries would be in the proportion of $\frac{13}{8} \times \frac{1}{2}$, or 13 for the 12″ battery and 16 for the 8″ battery. This is the relation of the *quantities* of offensive energy generated. To make the comparison more complete, a factor representing the relative *qualities* of the two energies should be introduced. This factor would vary in each engagement with the nature of the target, depending upon its relative vulnerability to hostile energy in the form of 12″ projectiles and 8″ projectiles in movement. It will be sufficiently accurate for the present purpose to assume that the average target with which the vessel is designed to engage is equally vulnerable to the two kinds of energies, that the quality of unit quantity of energy is the same for both batteries. The weights to be given to the two batteries become then 13 and 16 for the 12″ and 8″ respectively, and the increase in the total effective angle of the two batteries combined, due to the system proposed, would be the following:

Increase due to an increase of	
$\frac{1}{3}$ in the 12″ battery	$\frac{1}{3} \times \frac{13}{29} = \frac{13}{87} = .149$
Increase due to doubling the angle	
of the 8″ battery	$\frac{16}{29} = .552$
Total increase	$\frac{61}{87}$ .701

The total effective angles of fire of the heavy guns in the two cases are thus in the proportion of 1 to 1.7. Suppose T equals $\frac{61}{87}$ the mean interval of time necessary to generate unity quantity of muzzle energy for the guns mounted on the Iowa, and suppose T' the same interval for the guns mounted on the system proposed, then the relative total effective power of the two systems would be in the proportion of 1 to $1.7 \times \frac{T}{T'}$. The value of T is easily found, knowing the rapidity of fire of 8″ and 12″ guns. The value of T' will depend on the efficiency of the mounts in reducing the interval required in lowering and lifting, and in training to and from the loading position. T' may be expressed as equal to $T + t$, where t represents the time required in performing the additional operations incident to the system, and the relative power would be as $1.7 \times T$ to $T + t$.

Represent $\frac{T}{t}$ by e, the efficiency of the mount; then the relative power is $\frac{1.7}{1+\frac{1}{e}}$.

This equation shows how the advantage in gain would be easily dissipated by slowly acting mechanism, particularly as the caliber becomes smaller when the value of T, the time between shots, is small and the value of t is relatively larger. It would be useless, other things being equal, to have two guns available against a target instead of one if they fired only half as rapidly. The value of t will comprise t_1, the time to revolve from the bearing of fire to the disappearing position, t_2 the time occupied in descent, t_3, the time occupied in rising, and t_1 again, the time required to revolve back to the bearing of fire. Assume, for simplicity, that the conditions are those for heavy turrets. Taking the mean angle of rotation as 90°, the time t_1 required would be about 5 seconds with efficient training mechanism. Allowing 3 seconds for descent t_2, and 15 seconds for ascent t_3, the value of t becomes 28 seconds, say $\frac{1}{2}$ minute. Taking T as 3 minutes, T' becomes $3\frac{1}{2}$ minutes and $\frac{T}{T'}=\frac{3}{3\frac{1}{2}}=\frac{6}{7}$. The ratio would be smaller, as stated above, for smaller turrets. The relative offensive power of the two systems becomes $1.7\times\frac{6}{7}$ equals 1.45. The loss in rapidity of fire would be greater with imperfect mechanism.

Thus, in sum, the gain in power of battery, which at first sight appears so great on account of the large increase in angle of fire, will depend on the success with which the mechanical difficulties are surmounted, on the efficiency of the mechanism for effecting the operations incident and necessary to the system.

V.

Increase in protection and not increase in angle of fire was the object that gave birth to the disappearing mount. The birth took place on shore about a century ago and was produced by the increase in accuracy of fire which necessitated improvement in the methods of gun protection, for the guns, being the main elements in the infliction of injury, the immediate object of battle, and being

mounted usually in commanding positions, form the most important target for the concentration of hostile fire. These improvements took the form of minimum embrasures and disappearing mounts. On a disappearing mount, the gun is in view of the enemy only in the firing position. After firing, it disappears into a position more or less secure, where it remains during the process of loading and now usually during the process of pointing, the object sought and partially realized being the reduction to a minimum of the time of direct exposure. The security of the housed position is realized by the use of earth, masonry or armor, or a combination of these means, with or without the additional security of invisibility. The security is practically perfect where the gun disappears behind or under unbroken covering that gives no indication of the spot. Where such conditions can be realized, the advantage of the disposition is overwhelming; the enemy has no target, he may not have the range, and he cannot accurately keep the bearing. A few years ago, a dummy 10″ gun was mounted on a disappearing carriage off the coast of England and was made to rise and fall at regular intervals giving out a puff of smoke like a gun in action, while it was fired on by all the battery that the battleship Sultan could bring to bear and it was found that absolutely no effect could be produced, though the conditions were most favorable for the attack.

Thus ashore the disappearing principle has decided military advantages, and the inherent practical difficulties of the mount are not of great importance. In many cases, like the one just cited, in particular those of batteries covering sea approaches, where the guns can be scattered and where no objects would indicate the positions of the gun pits, where the enemy as a rule, will lack guns adapted to oblique fire, the only fire to which pits are seriously exposed, even in the case of the enemy possessing accurate knowledge of the range and bearing, in these cases, the advantage of the disappearing principle is so pronounced as to insure practically a perfect defense, without the expense of armor, having a sea-borne enemy at a hopeless disadvantage, exposed to injury and powerless to inflict it in return. When, however, the position remains visible, forming a permanent target, the conditions change, and the methods of defense common to other mounts, earth, masonry and armor, must be resorted to.

When the position is vulnerable and its welfare is essential to the gun, conditions can be imagined where it might be more advantageous for the gun offering a small target to remain in sight and invite fire, much of which would pass over, which, if aimed at the position, would strike it. The value of a vessel of war, as measured by her power to inflict injury, depends on the power of her weapons and on her power or ability to use them. Moreover, it results from a product of these two interdependent elements, which is greatest when both elements are large together. It would be needless to have powerful weapons, if use could not be made of them. The power to use the guns of a vessel in action will depend on the power to maintain alike their own integrity and the integrity of the platform that carries them; will depend alike on the protection afforded to guns and their crews, and the protection afforded the hull. It would be useless to have well protected guns if the vessel sank or turned over, or changed trim, or heeled to such an extent as to render their use impossible. It would be unwise to overprotect the guns and underprotect the hull, or *vice versa*.

With turret guns as usually mounted on battleships, the breech, including about ½ the length, is protected by heavy armor. When pointing at right angles to the angle of fire, the breech may be said, in the comparative sense adopted, to be perfectly protected. When pointing in the direction of the line of fire it is exposed to projectiles that may enter the gun ports and explode.

If the breech plug were closed at the time of explosion, the breech proper being cylindrical in form and fitted and held to the platform by straps, not trunnions, could stand heavy impact from fragments of projectiles without being seriously injured. If the breech were open and a shot or fragment struck the breech plug it would be disabled without doubt. On the whole, the breech of the gun is but slightly vulnerable. At the Yalu, a fragment, entering under the hood and deflected downward, killed the whole crew, but did not affect the guns.

The chase of the gun is exposed in the open, including about one-half of the total length. A shot from a gun of ½ the calibre, striking normally, would probably disable the gun, but the form is cylindrical, and when struck in a line deviating from the radius of a section, offers an oblique surface of large resistance, the

obliquity increasing rapidly as the direction of the impact varies from the radius. Further, a considerable indenture could be cut in the wall of a gun without disabling it, the strain in a longitudinal direction on a cross section being small.

Guns being now mounted in beds and strapped to the platforms, not as formerly on trunnions, a shot would strike the chase with considerable force and leverage without springing the securings of the gun. On the whole, the chase of the gun, though more vulnerable than the breech, could receive large punishment without disabling the gun.

In the Yalu the chase of a gun of moderate caliber was struck near the muzzle by a projectile from the secondary battery without disabling the gun or interfering with its fire.

Figure No. 9 represents the results of target practice with the 6″ guns in the U. S. Navy at ranges from 1000 to 1500 yards on the following vessels: Atlanta, Baltimore, Bennington, Boston, Charleston, Chicago, Concord, Newark, Petrel, San Francisco and Yorktown. The total number of shots fired was 340.

If a gunport of a 13″ turret had been the target, twelve shots would have struck it. The probability of a single shot striking was thus $\frac{12}{340} = \frac{1}{28}$.

If the center of the chase of a 12″ gun as protruding from the turret had been the target, twelve shots would have struck it. Of these twelve, four striking obliquely at an angle of less than 30 degrees may be considered as ineffective; eight may be considered as effective, and the probability of a single shot being effective is $\frac{1}{42}$.

If the center of the turret had been the point aimed at with the guns at right angles, the chase of the gun, if pointing to the left, would have received four shots, if pointing to the right, one shot, of which total two would have been ineffective, giving a mean probability of the chase being hit effectively of $\frac{3}{340} = \frac{1}{113}$.

Thus the gun as a whole, with the chase exposed to fire from direction perpendicular to the line of fire and the gun ports exposed in the direction of the line of fire, offers a target of small dimension, and, in the case of the chase, disposed horizontally in the most

advantageous manner. Thus the gun proper is only moderately vulnerable, and has small probability of being struck effectively.

The carriage and platform and their gear, including the elevating gear and loading gear, and mechanism for controlling the training gear and ammunition hoist, below, are exposed in the same manner as the breech to fragments of projectiles entering the gun ports and exploding, and their vulnerability is greater than that of the breech of the gun, though in the case occurring at the Yalu, cited above, none of their gear was disabled.

The gun's crew assembled around the breech is exposed in the same way, and is more vulnerable. All its members were killed in the case cited. On the other hand, the number of the crew is small and if the precaution has been taken beforehand of training other men in the duties, the crew or part of it can be replaced.

This assemblage of objects near the breech of the gun presents by far the most vulnerable feature, though they can be reached only by projectiles entering the gun ports. These projectiles are not limited in size; the smallest R. F. projectile entering and exploding could inflict irreparable injury, while, if it struck the chase of the gun, it would be without effect. It might be pointed out at this point that the gun ports as now fitted, for the reason just mentioned, are most dangerous targets, but shields carried externally could be devised, which, while moving with the gun, would effectually close the openings.

The fixed part of the turret extending to the armor deck, properly covered above by a platform of sufficient thickness to catch fragments, and without connection with the objects inside, so that bulging or displacing slightly will not affect the objects inside, offers a perfect protection (speaking in the comparative sense) for the supports of the movable parts of the turret and for the ammunition tubes, while the training gear if properly placed below the armor deck would enjoy a similar protection.

Thus 12″ turret guns on a seagoing battleship, considered as a whole, from the point of view of protection, present a vertical cylinder extending from the armor deck to the top of the movable turret, a vertical target of a total area of 750 to 800 sq. ft., in usual cases, which is completely protected over its whole surface except at the gun ports which present two elliptical areas of about 12 sq. ft. each, with a vertical diameter of 4′ 3″, together an area of

about $\frac{1}{32}$ of the total area of the vertical target. This area is of a most vulnerable nature, though the vulnerability could be reduced if not entirely annulled by the fitting of port shields. This cylinder carries in addition, when the guns are trained perpendicularly to the line of fire, a horizontal area about 20′ long, 20″ high at the outer and 40″ at the inner end, making a target of about 30 sq. ft., about $\frac{1}{25}$ of the whole area, of partial or moderate vulnerability and small probability of being struck effectively.

Thus on the whole, assuming that the gun ports are protected by shields, the system composing the heavy turret guns, their fittings, and accessories, is well protected, offering but very small vulnerable areas, with slight probability of being struck effectively.

VI.

To serve her function the vessel must float, must maintain her floatability against the intrusion of water. This can be done by protection against the opening of breaches through which water might enter and by the reduction of the quantity of water that would enter a breach, or a number of breaches if made.

Water can enter by steady flow only through breaches that are made below the water level. It can enter by swash through breaches above the water line, but near it, the nearness varying with the condition of sea.

Since projectiles cannot reach the vessel below the water, protection against them, as far as floatability is concerned, could be secured if armor of sufficient thickness could be worked on the sides over the region liable both to attack by being emerged and to intrusion of water by being immersed.

A vessel of 70′ beam, rolling 20°, a roll common in seas where engagements would be entered into, assuming for simplicity that she is wall sided in the region in question, would emerge on one side points that were 12.7′ below the surface of the water when on an even keel and would immerse on the other side points that were 12.7′ above the water line. With a 20° roll, the region thus exposed to injury at one time and to submersion at another on the vessel in question would extend over a height of 25.5′ from end to end. On vessels whose side armor is best disposed for protection of floatability, extending in complete heavy and light belts, the

region protected by heavy armor extends from about 4.90′ below the L. W. L., to about 1.65′ above, and the region protected by the light armor, from the top of the heavy belt to a mean height of about 3.9′. Of the total height exposed on the above supposition, .255 is protected by heavy armor and .153 is protected by light armor, .592 being unprotected.

The portion behind heavy armor cannot like objects behind turret armor be considered as perfectly protected, for the armor tapers to less than half the maximum thickness, which is about the same as the uniform thickness of the turret armor, from the upper to the lower edge, and from amidships to both extremities, while the mean surface of impact will on the whole be much less oblique than that of the turrets. The region covered by light armor is not protected against breaches from guns of medium caliber.

The parts covered by neither heavy nor light armor, .59 of the total, are exposed to breaches being made by projectiles of all calibers and may be expected to be riddled by those of small caliber in an engagement of any length with an enemy of creditable marksmanship.

Thus, on the whole, on the supposition of a 20° roll, the vessel's floatability is exposed to breaches which would allow the intrusion of water over an enormous area along the total length, of which only $\frac{1}{4}$ is protected by heavy armor and less than $\frac{1}{8}$ by light armor, the protection from which is only partial. The Iowa on the supposition of a 20° roll offers a total surface of 8925 sq. ft., of which 1946 sq. ft. are protected by heavy armor, 555 sq. ft. above and 1391 sq. ft. below the L. W. L., 779 sq. ft. are protected by light armor, and 6200 sq. ft. are without protection.

This supposition of a 20° roll is but moderate. A battleship is expected to give battle in conditions of sea where water mounts much higher on the sides than in a roll of 20° and where actual rolling may occur exceeding this angle.

The conditions are of course less severe where the sea is more moderate, and could be assumed much less severe for coast defence vessels.

The quantity of water that will enter a breach or number of breaches can be reduced by causing the breach to close wholly or in part, by subdivision, and by the presence of water excluding materials.

The use of mats and plugs to close breaches in metal vessels can be considered, at best, but slightly practicable.

The use of materials which, swelling from the effect of water, tend to close the breach is of questionable efficiency, and is limited in its application to a small region covering from $\frac{1}{2}$ to $\frac{2}{3}$ of the height of light armor in the case above cited.

Subdivision is the most effective way. It reduces the quantity of water by diminishing the space to which a breach in the side may give access.

The total space may be considered as divided horizontally into two distinct parts. Water entering on one side of the armor deck is accepted as limited to that side only if so desired. After an engagement of consequence has lasted some time this subdivision must be considered as incomplete, particularly now that the armor deck is subject to contact explosion of projectiles carrying high explosives or large charges of powder entering at an angle above the side armor. The horizontal subdivision by other decks and platforms can be considered at best as only partial.

The vertical subdivision by transverse and longitudinal bulkheads is highly developed below the armor deck. Above this deck it is but slightly developed (the case in question being a battleship as above) and includes the cofferdam above the heavy armor, which is used with or without the obturating material for closing breaches.

The effect of a breach in the side from a projectile above or a torpedo below water on the subdivision in that region will vary, but in each instance the resistance of the thin plating of bulkheads even to fragments of small dimensions is very slight. Access will be made not only to the compartments in which the breach is made, but also to other compartments in the line of the trajectory of a projectile not exploding, and to all compartments in the neighborhood in the case of a projectile exploding, except where the explosion occurs in coal, which, when well placed, covers in varying thickness part of the top and the whole of both sides of the space devoted to motive power.

The floatability of a well planned battleship will not be destroyed by the filling of the two largest compartments, but her efficiency would be greatly reduced, the plane of floatation being considerably altered, reducing the reserve buoyancy, the stability and the

efficiency of the battery and the motive power. It would cause a sinkage sufficient to submerge the top of heavy armor belt.

Further, the efficiency of subdivision will always have a coefficient of reduction depending on the efficiency of the personnel and the fittings for guaranteeing the bulkheads against the openings that are made in them.

A third cause reducing the quantity of water that may enter flooded compartments is the presence of other materials which exclude their own volume from the volume accessible to water. On battleships, light materials for this special purpose are carried only on the unarmored ends, above the armor deck. The obturating materials of the cofferdams also serve this purpose, and the coal as usually stowed preserves about $\frac{7}{10}$ of the volume it occupies. In all three of these cases the subdivision of the space is more or less minute. Whereas, the large compartments whose flooding would be most serious cannot be stowed with water excluding materials.

Against the ram and torpedo, armor protection is not practicable. Destruction or avoidance of the agent is the only method. As the range is zero for the ram and as the guns to which the agent is vulnerable at short ranges are not likely to be found out of action, the probability of being rammed under normal circumstances is small. The probability of being torpedoed on the other hand is greater as the range of the torpedo may be considered at the extreme as 1000 yards. Though the accuracy of fire is small, the agents may be numerous.

These agents as a steady target would be most vulnerable to the fire of the smallest caliber of R. F. guns, but their diminutive size and swiftness may afford comparative protection under certain conditions of attack notwithstanding the development of the secondary batteries and the use of the search lights, and the use of torpedo nets.

Experiments in Italy go to prove that three thicknesses of plating spaced apart, are insufficient to overcome the effects of torpedo explosion. The outer and inner bottom and the wing longitudinal bulkhead will be inadequate, notwithstanding the fact that the wing passage is left empty so as to transmit as little as possible of the force of explosion, and the probability is that the large compartments in wake of the explosion, unless fitted with two wing

longitudinal bulkheads, would be flooded and endanger the floatability.

Though, under normal circumstances, the probability of being torpedoed is small, and the probability of being rammed is much smaller, the consequences in each case are most serious.

In sum, the first requisite, floatability, is at best but partially protected. It is in greater danger than the heavy turret guns. The probability is, that the most efficient type of battleship yet afloat while engaging under the conditions for which designed, if stability is not destroyed previously, will sink before all her heavy turret guns are disabled, the turrets having been supplied with port shields.

If additional cost and weight are available for protection they would be more efficiently expended in increasing the protection of floatability by increasing the area above the water line protected by light armor and by increasing the power of the secondary battery against torpedoes, than by adding to the protection of the heavy turret guns.

VII.

To serve her function a vessel must not only float but must float right side up. Integrity of battery and floatability would be maintained in vain if the vessel turned over.

Stability like floatability is overthrown by the intrusion of water.

Water entering in any part will cause sinkage and reduce the freeboard and the range of stability particularly when it causes an initial heel causing capsizing at a smaller angle of heel, but entering in particular parts under certain conditions its effects are serious and pronounced in another way by influencing the quantity or amount of stability within the reduced range, affecting the righting arm, the magnitude of the upsetting moment required to cause a given heel.

This result is produced by the effect on the position of the center of buoyancy, on the length of the metacentric radius, on the vertical position of the center of gravity of the vessel, and on the shifting character of the weight added, the first two affecting the position of the metacenter, the last two the position of the center of gravity, the sum of all effects being the influence on the metacentric height.

The position of the center of buoyancy will probably not vary greatly. The compartments liable to be opened up to the sea will probably not be found, on the whole, to vary far in vertical position from the center of buoyancy found at about $\frac{2}{3}$ the mean draught below the load water line. On battleships with unarmored ends, the riddling of these ends will cause the center of buoyancy to be lowered, but on the other hand the gain of buoyancy by sinking to balance the loss of buoyancy by the filling of low compartments will raise the center. On the whole, the change in position of the center of buoyancy is but a small element in the probable reduction of metacentric height. The means of safe-guard are the same as part of those for floatability; an increase in the protection of the upper compartments by increase in extent of light side armor.

The reduction in length of metacentric radius will be in direct proportion to the reduction of the moment of inertia of the water plane and to the increase in the volume of displacement.

The accumulation of water in the course of an extended engagement may materially increase the volume of displacement, but the effect is not so serious on this score as it is in diminishing the reserve buoyancy and reducing the range of stability.

The effect depends as for floatability on the amount of water that enters; the inadequacy of the protection is best remedied as in the case of floatability by increasing the extent of light side armor.

The probable reduction to the moment of inertia of the water plane in an engagement is most serious. This is the largest factor that enters to determine the range of stability and the amount of stability in this range; it is the great reduction in the moment of inertia of the water plane caused by the edge of the deck going under or otherwise, that causes capsizing in the usual cases.

If the vessel floated on an even keel in a smooth sea, the danger would be very small except in the cases of battleships whose belt armor is of limited extent leaving large portions of the water plane on the full ends exposed or only partially protected by the presence of water excluding materials.

But when the vessel rolls even slightly, about 3°, her heavy belt is submerged and the actual water plane has only the protection of the light belt, which in English types extends in the

form of box armor but a limited distance amidships. The light belt is submerged in vessels with complete belts at the moderate roll of 9°, and above its top the water planes have no protection. Here the vessel's sides will have breaches made by projectiles of all calibres, the effect being most pronounced on the side opposite the side struck, where fragments tear off great lengths of plating.

Thus after a prolonged engagement the vessel on rolling will reach at moderate angles points where the moment of inertia of her water plane will be seriously compromised.

Thus the length of the metacentric radius is but partially protected for angles of roll caused by an ordinary sea swell, and is but slightly protected if not altogether unprotected for angles liable to occur in moderate seas in which battleships are expected to engage.

Amelioration lies along the line of increase of extent of light side armor.

The vertical positon of the center of gravity of the vessel will be affected by the quantity of water that enters and its vertical position after entering.

Remarks on quantity of water liable to enter are given above in the consideration of the subject of floatability.

The vertical position of the water will depend on the position of the opening through which it enters and the disposition made of it after entering.

Openings are liable to be made below the armor deck by torpedoes and can be made as above mentioned, by projectiles piercing the heavy belt or entering below the heavy belt when the lower edge is emerged in rolling, which occurs ordinarily at about 8½°, and by fragments projected downward in the blast of projectiles containing high explosives or large charges of powder, exploding in contact with armor deck. It is not likely that such openings below the water line will be stopped in action and in consequence the compartments flooded may be considered as permanently flooded, it not being practicable in most cases to drain to other compartments or pump out while the openings are unstopped.

The position of the water entering below the armor deck may thus be considered as fixed and its effect on the center of gravity of the vessel, which is usually in the vicinity of the load water line, is to lower it.

Openings above the armor deck made through light armor and in the unarmored sides are liable to only intermittent flooding due to immersion from the rising of waves on the side and from rolling. Water is thus able to collect on the armor deck and on the berth deck and gun deck.

The quantity that enters will depend almost wholly on the condition of the sea and the rolling properties of the vessel. For water entering and collecting on the armor deck near the water line, the breaches will be less pronounced, less numerous and more easily closed or partially closed than water entering above a higher deck, but on the other hand they will be more frequently and for longer periods under water; but being a shorter distance above the center of gravity, this water will have a less marked effect in raising the center. In both cases the quantity can be rapidly reduced by an efficient system for clearing the decks, from the gun deck through scuppers or special ports overboard, from the armor deck through special non-return valves overboard or else through a special system of pipes leading to special compartments in the bottom of the vessel, in communication with the pumps, which latter arrangement causes the water entering above the center of gravity to pass below it.

On the whole, the water entering the vessel, even when the engagement is in a seaway, when the arrangements for clearing the armor and gun decks are efficient, will tend to lower the center of gravity.

Water on board is liable to affect the horizontal as well as the vertical position of the center of gravity. Under the influence of gravity it tends to flow toward the side of the roll or heel and increase their amplitude and danger.

It may be looked on as causing the center of gravity under heel to move out toward the center of the buoyancy, reducing the righting arm, or as an upsetting moment that sets in. The effect is proportional to the quantity of water multiplied by the horizontal distance through which it shifts.

The quantity of water liable to enter is considered above.

The longitudinal subdivision below the armor deck will prevent extensive shifting of water except in the case of large compartments partially filled.

On the armor deck partial and complete longitudinal bulkheads

or simple "barrages" are or can be fitted to reduce the shifting. On the gun deck usually no means are provided, and accumulation of water on the deck endangers the stability.

In an ordinary case of a battleship of moderate size, water accumulating to a depth of 6″ on the gun deck by running over to the side of the roll will deduct about 10″ from the righting arm, or $\frac{1}{3}$ to $\frac{1}{4}$ of the maximum righting arm.

In the intact condition this reduction would cause the righting arm to disappear and the vessel to capsize at 10 or 15 degrees less angle of heel or roll.

In an engagement in anything like a heavy sea, this element becomes serious; large quantities of water are liable to collect on the berth and gun decks, and, flowing from side to side without obstruction, to endanger the righting arm at large angles, particularly in the rolls to leeward, where the wind would superpose an additional upsetting moment.

The entering of water on one side below the armor deck, though not shifting, would materially affect this element of stability by causing an additional upsetting moment, an initial heel to the side bilged, reducing thus the range of stability and the effective righting arm during the roll to this side.

This effect could be partially remedied by the admission of water on the other side, but it would be at the expense of reserve buoyancy and the other elements affected by the admission of water in the region in question.

In sum, the protection to stability is partial at best, the two elements, loss of inertia of water plane and the accumulation of water on the armor deck and decks above the armor deck, becoming of increasing consequence as the sea rises.

Taken altogether, for all seas in which a battleship is expected to engage, the protection to stability is less than the protection to turret guns. In an engagement in a moderate sea, under ordinary conditions, the vessel would capsize before all the heavy turret guns are disabled, and where the vessel is of somewhat low freeboard, and efficient means are not provided, and used for clearing water from decks above the water line, and transferring it from one side to the other, where practicable, or flooding other compartments to counteract the heeling effect, under these conditions particularly when the sea is running at all high, the probability is that the vessel would capsize before foundering.

If additional cost and weight are available for protection, they would be more efficiently devoted to increasing the protection to stability, by increasing the extent of light side armor than to increasing the protection to heavy guns.

VIII.

The admission of water will almost invariably be unsymmetrical, and will cause heel and change of trim, affecting thereby various elements of efficiency. The extreme elevation of turret guns as usually mounted being 15° and the extreme depression 5°, a heel to one side of 5° would render it impossible for guns training toward the opposite side to attain a point blank range; a heel of 10° would cause these guns at extreme depression to fire over any vessel engaging at moderate ranges; a 15° heel would make these guns wholly unserviceable, while the gun on the side of the heel could then only attain an elevation for point blank range.

A heel of 3° would submerge the top of the heavy belt, and a heel of 9° will submerge the top of the light belt. A heel of about 8½° will emerge the lower edge of armor.

Thus only moderate angles of heel will materially reduce the efficiency of the battery, and will reduce the protection to floatability and stability, and even expose permanently or periodically all the vitals.

Change of trim will reduce the efficiency of protection to both ends and will affect, in a less marked degree than for heel, the efficiency of the battery. Both heel and change of trim will reduce the speed by increasing the resistance and reducing the efficiency of the screws. They will ordinarily occur together and the total result when pronounced becomes particularly serious in the reduction of stability.

IX.

The protection of what may be called the vitals, the parts containing the elements of mobility, of governability, and the substances of explosive character, situated below the armor deck, has been involved in the consideration of protection to floatability, stability and uprightness.

The weakest point in this protection in all battleships except those recently designed in France, is the lack or insufficiency of provision for catching fragments caused by the explosion in contact with the armor deck of projectiles containing high explosives, or large charges of powder. Experiments in Italy have shown that the armor deck is shattered in the region, and that the fragments of the deck are projected downward with high velocities, which simple plating cannot check.

To protect the objects below, a heavy splinter deck or second armor deck is necessary at some distance below the armor deck, unless the side armor is fitted, as in the English battleships of the Majestic class, to prevent a projectile, carrying high explosives or a large charge of powder, from reaching and exploding in contact with the armor deck.

With the existing dispositions, excepting in the instances named, the protection to the vitals is not equal to the protection to the heavy turret guns. Under the probable conditions of coming engagements, the probability points to the destruction of motive power, or steering power, or boiler explosion before the disabling of all the heavy turret guns.

Additional weight and cost would be more efficient, devoted to a splinter deck or second armor deck, partial if not complete, than to increase of protection of heavy guns.

X.

The protection of the secondary battery, considering its great and increasing importance, like the protection to the other elements considered above, is not in due proportion with the protection to heavy turret guns, though increased attention is now being paid universally to the subject.

The crews of the turret guns are small and constitute but a small fraction of the personnel stationed above the armor deck in action. Casualties among this larger fraction will be great. The destruction in the Chino-Japanese engagements, to personnel and objects, unprotected or protected only by shields, was terrible.

The case of the Chen Yuen, at the Yalu, may be cited. None of her heavy guns were injured, and yet 76 per cent. of her crew and officers were killed or wounded.

The explosion of projectiles produced terrible effect on everything unprotected; exploding between decks, whole sections of objects on both decks were disabled, and the effect was proportionally large for rapid-fire projectiles of small caliber. A 6-pdr. projectile exploding in a military top of the Ting Yuen killed seven men, probably all those present. The usual effects of such explosions must be of serious consequence in their terror or panic producing effects.

Additional protection, increase of light armor tending to reduce the number of explosions on the inside, would be more efficient than additional protection to heavy turret guns.

Referring to military tops, it is to be noted in this connection that the model represents the masts as rising and falling like the turrets, though no attempt is made to meet the practical impossibilities of the disposition.

As the fire of top guns could be most effective under certain conditions, at short ranges, particularly against the tops of barbettes, and uncovered redoubts, and as the exposure is very great, and the top guns, as shown in the Chino-Japanese war, cannot hope to survive for this close range, it would be a great gain, if some method could be devised for preserving their integrity until the desired moment. Though it is practically impossible to raise and lower the mast, it would not be so difficult to raise and lower the top or tops, leaving the mast standing permanently, needed as it is for signaling. The damage done by shell hitting the masts is not great; they pass through before exploding. The mainmast of the Ting Yuen at the Yalu was struck twenty times without undermining its power to sustain the top.

The same slight effect was noticed in masts and smokestacks generally. One smokestack of the same vessel was struck forty times without seriously affecting its efficiency.

The probability is that late in engagements the masts could still sustain the hoisting of tops and their contents. This operation, as well as the housing of the tops below deck with perhaps slight surrounding protection, the securing in place after hoisting and the securing of the masts, present obstacles which though great, are not impossible of being surmounted.

The idea need not be limited to the usual military masts, but could be applied to platforms raised on one or more supports in

various parts from housed positions to positions of various elevations carrying light guns. This would add to the protection of the objects least protected. This feature of the model can be disposed of with the remark that it contains the germs of suggestive possibilities for useful application for purpose of protection, though in the form presented it is utterly impracticable and is unaccompanied by any attempt to meet the practical difficulties involved.

XI.

Summing up the results of the consideration of the relative protection of the heavy turret guns and the other elements of efficiency of a vessel of war as embodied in a battleship, it has been found that the latter, floatability, stability, uprightness, vital organs, secondary battery, and personnel, each and every one, are protected in a less efficient degree, supposing the use of shields or doors for the ports of the turret guns.

To advance toward the equality of protection that would produce the highest resultant efficiency of the vessel, toward the infliction of the maximum amount of injury under the conditions for which designed, toward arriving under such intended conditions of engagements, at the desired point where the offensive and defensive power would disappear together, when the last of the personnel and secondary battery would be destroyed, the vitals pierced, uprightness undermined, and the last heavy turret gun disabled at the moment that the vessel foundered, capsizing as the last vestige of buoyancy went under; to advance toward this ideal combination, it would be more advantageous to expand effort available for protection in increasing the protection of the elements enumerated rather than in increasing the protection of the heavy turret guns.

To subserve this purpose most effectively the effort should be directed toward the increase of the area covered by light side armor, employing it as much as possible for the protection of the secondary battery, and toward the working of a heavy splinter or armor deck well below the usual armor deck, and, where sufficient weight is not available, the division of the available deck armor between two decks instead of confining it all to one deck.

Thus increase of protection to the heavy guns of a battleship does not present a reason of weight for the adoption of a different mount. Heavy turret guns as now mounted may be said to be over-protected.

From the standpoint of protection, if the mount is adopted for other reasons, it would be well to provide for the possibility, where desired, of continued fire from the elevated position with adequate supply of ammunition without returning to the housed position for loading. For it would be better to invite fire on the gun than to have it concentrated on other elements less protected and equally essential to efficiency, particularly as the gun presents its small and slightly vulnerable target above the upper deck where most of the shots aimed at it would miss entirely, which, if aimed at other parts along the hull, though missing these parts, would hit the hull, many of them inflicting damage that might be of serious consequence.

Referring to the target (Fig. 9), it will be seen that if the center of the turret on the upper deck had been the center of fire, 129 shots would have passed over the vessel, wide of the turret, which, if the center of fire had been the water line, would all have struck the hull of a vessel of $17\frac{1}{2}'$ freeboard.

Of course it would have been unwise in the enemy to direct fire on the turret or turrets, instead of the hull, but the former offers to a gunner a definite, inviting, vertical target on which to train, which causes shots to be directed on it notwithstanding instructions to the contrary, depending of course on the discipline of the gunners and the intelligence and persistence of those directing the fire. In the Chino-Japanese engagements, the objects offering vertical targets, masts, smokestacks, turrets, sponsons, etc., invariably received a concentration of hits. Of course no instructions were given to direct fire on smokestacks.

It may be noted here that the feature of being able to remain and fire in the raised position, would materially enhance the value of the system, from the standpoint of offense, by providing for the events, where the saving of time or increase of rapidity of fire more than counterbalances the reduction of obstruction, or any gain in protection.

XII.

There is not only small advantage along the line of protection in an increase of total protection to the turret guns, but the amount of this increase realized in the system proposed, is only moderate, supposing the guns to disappear for loading each time.

Referring again to the target it will be seen that thirty-eight shots would have struck a turret for 12″ guns, if the center of the turret had been the center of fire. This is the result of deliberate practice in time of peace, in smooth seas, at short ranges, with good marksmen. This excellent marksmanship for even these concurring favorable circumstances, gave only one hit in ten. Considering the limited number of shots that could be fired by guns of a caliber to match the turret armor when attacking it normally; considering the cylindrical form of the turret, offering oblique surfaces for impact; considering the slight probability of a projectile, of large caliber, directed against the turret, striking the chase or a gun port; considering the fact that the chase of the gun, even if disposed most favorably for attack, at right angles to the line of fire, offers but a narrow rectangle drawn out horizontally, which, selected for the center of fire in the target, would have been hit only once in thirty shots, and that the chase is cylindrical in form and of great resisting nature, so that but few if any, of the total number of shots striking, of the ordinary calibers that would be directed against it, would be effective; considering these facts, it is evident that in the conditions of battle, the heavy turret guns as at present mounted, are but slightly exposed. (It is assumed, as above, that doors or shields exist protecting the vulnerable gun-ports. As a matter of fact they are not fitted on any turrets now in existence, but, as mentioned above, there is no great difficulty in the way of fitting them, and this point should not enter to throw out the conclusions as to the system. It may be added that, with the turrets now afloat, a shot would be effective striking anywhere within the area presented by the port, when presented direct, except perhaps, in the case of a very small projectile striking the outer part of the annular surface presented by the muzzle of a gun. A projectile entering the bore to score the wall and strike the breech plug if closed and explode, or to pass through into the turret if the breech is open, or striking on the outside of gun, glancing along the surface of slight incline to enter the port and explode inside; under either of these conditions the probabilities of disabling the guns are great, even for projectiles of very small caliber. As mentioned above, taking into consideration the large number of shots fired by rapid-fire guns, the probabilities are that in an engagement many

projectiles, if fire is properly directed, will strike this area. In the case of the target cited above, the center of the port presented direct being the center of fire, twelve shots would have struck it, or about one in twenty-eight. The probabilities would be smaller in action for the reasons cited above; but the large figure indicates the great exposure of this vulnerable point).

The disappearing system as proposed reduces the exposure to practically zero while the guns are below deck, provided the cover is sufficient for protection from above, and the amount of exposure of the turret guns usually mounted being small as just pointed out, the gain in reducing this amount to zero is equally small. This gain lasts while the guns are below deck which would probably be about $\frac{2}{3}$ of the time. When the guns are in the firing position the exposure is greater than that of the turret guns, incident to the protection of only light armor, which would offer probably about $\frac{1}{2}$ to $\frac{1}{3}$ the resistance or protection of heavy turret armor.

If only part of the guns appeared at the same time, an operation necessary for the realization of the increase of angle of fire, the enemies' guns could be concentrated on them, to be shifted to the others replacing the first when they disappeared. Under these conditions the guns with their inferior protection though exposed but about one-third of the time, would receive not a great deal less than the same total amount of fire. In addition the guns with their accessories and fittings are more delicate and more easily damaged in the proposed system.

The total possible gain of protection by the proposed system thus depends on the length of the time spent in the raised position of greater exposure compared with the length of time spent in the loading position of greater security.

Considering the time required in lifting the weight through the altitude needed, the guns beginning to be exposed the moment the top of the shield rises above the deck, the time required for training to the bearing of the enemy, for deliberation in aiming on account of the unsteadiness of the platform, for training back to the position for disappearing and for descending gently to the position for loading; considering that during all this time, probably one-third of the total time, the more fragile objects are under greater exposure, the resulting total gain in protection realized by the system can be but moderate under the best conditions of solution of the mechanical problems.

Thus, in sum, there can be but slight advantage in increasing the total protection of turret guns, and the maximum possible gain in total protection to be derived from the proposed system is small and will depend on the perfection of the mechanism. Thus, from the standpoint of mean total quantity of protection there is not sufficient advantage in the disappearing system proposed to warrant a departure from the usual turret mount. However, if the property of remaining at will in the raised position is reserved, the nature of the protection which is constant in usual cases will be variable at will with the disappearing guns proposed varying from a minimum sufficient for projectiles from rapid-fire guns, to a maximum greater than that of the heavy turret guns.

The exposure of the guns will vary between wide limits during all probable engagements of battleships. During times when the probability of being hit by projectiles from heavy guns is small, the protection to heavy turret guns in usual cases is excessive and out of proportion to the exposure; the great thickness of armor is a useless weight; thickness sufficient for projectiles from rapid-fire guns would be sufficient.

During the times when the probability of hitting with heavy guns is almost certain, an absolute protection for the heavy guns would not be excessive; at moments when the power to withdraw the heavy guns entirely from exposure might be most valuable, particularly, if perchance, the other heavy guns had already been disabled; at these moments of close range the time required for sighting is small and the time of exposure with the proposed system in order to use the guns' powers of offense is resultantly small and could probably be regulated without great delay of fire to correspond more or less to the time of loading for the enemies' heavy guns.

On a vessel of war, where everything is compromise, where every addition to one element entails a sacrifice to other elements, protection is best when it is proportioned to exposure. With the variable exposure of the guns of a battleship, the protection afforded by the disappearing system proposed, varying more or less at will from a minimum sufficient for projectiles from rapid-fire guns to a maximum greater than the protection afforded by a heavy turret, is superior in *quality* or nature to the protection of heavy turrets.

Moreover, this variable property permits the regulation, within limits, of the gun protection to suit the protection of the other elements, which together may be called the hull. Under certain conditions of engagement, the full possible protection may be reduced and a corresponding increase in the offensive power realized. For instance, engaging bows on in a smooth or moderate sea at moderate ranges or in a heavier sea at shorter ranges, the after guns would remain in the raised position, the forward guns alone disappearing after firing. The exposure of the after guns would be somewhat increased, as it would last during the loading period of the forward guns and the partial protection offered by these would continue only while they were in the firing position; but this protection would be ample under the conditions and the rapidity of fire of these guns could be increased and the advantage of their increase could probably be realized without conflicting with the fire of the forward guns. Under these conditions the protection would be adequate, while the offensive power would be nearly double that of guns mounted in the usual manner where the after guns could not be brought to bear.

There is another difference in the nature of the protection in the two cases of ordinary turrets and of the system proposed arising from the moral effect on the personnel of the guns. The consciousness of invisibility would give to the disappearing crew a strong sense of security out of proportion even to the actual security while the same invisibility would cause the crews of attacking turrets to have a sense of disparity of security out of proportion to the reality. The disappearing crew would feel at advantage, and the crew of the attacking turret of usual form at a disadvantage, causing a marked effect on the efficiency of the service in the two cases to the advantage of the disappearing system.

Summing up the comparison of the protection in the two systems it is found:—

That the possible mean total quantity of protection does not differ largely; the slight difference being in favor of the disappearing system. That the nature of *quality* of the protection differs; that for the disappearing system being superior on account of its variability, allowing adjustment to correspond to the exposure and to the relative protection of the hull, and on account of its moral effect on the guns' crews, causing a disparity in the sense of security

due to the element of invisibility favorable in the case of both crews to greater efficiency of the disappearing crew.

Combining quantity and quality the resultant protection is superior in the case of the disappearing system.

Summing up the comparison of the total effective power of heavy battery it has been found that in the proposed system, (1) the effective offensive power has been increased by the increase in angle of fire overbalancing the loss in rapidity of fire. (2) The protection is superior on account of the possible maximum protection being as great or a little greater, while the adjustable nature makes it more adaptable for shipboard, permitting adjustment to correspond to the exposure and to the relative protection of the hull, while a moral effect on the crews is produced to the advantage of the system.

Combining offensive power and power to use same, the resultant total of effective power of the main battery is greater in the case of the disappearing system.

However, as stated above, the gain in offensive power depends wholly and the gain in protection partly on the efficiency of the mechanism.

XIII.

Another important element in naval design besides the power of the main battery is involved in the question of weight, which differs in the proposed system from the usual turret system.

Armor of one-third to one-half the weight of heavy turret armor would suffice for the heavy guns. The saving of two-thirds the weight of heavy turret armor would amount to about 120 tons for a pair of 12″ guns. For two pairs the total saving would be about 240 tons.

On the other hand the mechanism required for raising the necessary weight, 120 tons, through the necessary height, 6 feet, in a reasonable time, 15 seconds, once every three minutes would require an addition to the weight of the hydraulic plant of a 12″ turret of about 30 tons, including additional pumping power and the quantity of water involved, one or more accumulators and a small air compressing engine for same, additional piping and fittings, account being taken of the fact that training and lifting will not take place together.

It may be remarked at this point that the additional weight and power required would be materially reduced if the energy of recoil and the energy of descent could be partly utilized to store up energy for ascent. It would be practically impossible to utilize the energy of recoil on account of the difficulty of connections to the accumulator, but the difficulty of utilizing a part of the energy of descent is not so great. Taking the additional weight for the two 12″ turrets at 60 tons, the net weight saved would be about 180 tons. With the 8″ guns, the conditions would not be exactly the same. It would be advisable, on account of their more rapid fire, to keep them in the raised position, except when a 12″ gun wishes to fire across the position. In consequence, it would not be advisable to reduce the turret armor to the extent taken for the 12″ guns.

On the other hand, a single plant amidships could serve for all four 8″ turrets and the additional weight of hydraulic plant would not be proportionally so large as for the 12″ turrets. (A single central plant might serve for all the turrets with an economy of weight.)

It may be taken that only sufficient weight is taken from the turret armor to compensate for the small increase in weight of hydraulic plant, and that the result does not affect the total weight.

The total saving in weight would thus be about 180 tons.

This amount is less than the saving in the case of simple barbette guns, and is less than the saving in the case of barbette guns protected by shield armor as on the English battleships Barfleur and Centurion, but it would still be a valuable saving, sufficient to aid materially in armoring a splinter deck over the boilers and engines or in increasing the extent of light side armor.

XIV.

Besides the general ideas or principles involved in the model, as considered above, there are certain necessary inherent features of this system which influence the desirability, possibility, and practicability of its application on board ship.

1. An architectural feature is involved in the change in the position of weights.

Supposing the thin armor carried by guns to be about one-third

the weight of turret armor and the lift to be 6 feet, the raising and lowering of the weight involved in the 12″ guns would cause a change of about $\frac{1}{15}$ in the metacentric height. If in addition the 8″ guns were mounted on the same principle and had a lift of 5 feet, the total effect would be a change of about $\frac{1}{10}$ in the metacentric height.

In passing from one position to the other, the radius of gyration of the vessel would be altered, increasing for the raised position.

The reduction in metacentric height would combine with the increase of radius of gyration to cause an increase in the period of roll for the raised position, which would give a steadier platform for the guns in the firing position.

Since the vessel would be designed for adequate stability with the guns in the raised position, the effect of this feature of the system is advantageous, both to stability and to steadiness of gun platform, though the effect is but small in extent.

2. In seeking to utilize the possibility of firing across the positions of other guns there will be danger of injuring the guns that may be in the operation of rising at the moment of the firing. This is a serious danger for the conditions of battle, however trained and careful the gun captain may be; in fact, it is dangerous to allow a gun the possibility of training to the extent of bringing into the field any other gun mounted on the same level. To remedy even partially this danger there would have to be a single mind in constant knowledge of the position, raised, lowered, rising or falling, of every turret, with the power to influence the firing of the guns in accordance with such knowledge. The difficulty of providing a single mind with such knowledge and with such control is a serious detraction from the plausibility of wholly utilizing for fire angles that are subtended by turrets. For volley firing, for a single volley or for successive volleys, in which the moral effect of invisibility, of appearing to fire and then disappearing, referred to above, would be great; for such firing, where the commanding or other special officer would direct and control the fire, the danger to guns would be less.

3. However efficient the mechanism may be, there must always be a loss in rapidity of fire of any gun. The influence of this loss has been considered above. Its effect will become greater and greater as the caliber decreases; the time required for the additional operations increasing in its proportion to the total time.

4. As mentioned above, the presence of turrets on the upper deck would cause many shots to miss. With the disappearing system the hull would receive much greater punishment, while, as demonstrated above, it is the weaker part.

5. The increase of mechanism, with its accessories and fittings would increase the complexity, and every increase in complexity increases the probability of accident and the danger of some important part not working properly in action when the smooth working of every part is of paramount importance. Simplification would result from the use of explosives or chemicals to shoot the weight up gently; but at present such a method is beyond the sphere of practical possibility and reliance must be placed on hydraulic power with or without association with compressed air, with the complexity of mechanism necessarily incident thereto.

6. A serious mechanical difficulty is met with in providing security when the guns are not in the housed position, against the friction when the guns are raised with the vessel inclined, against inertia of rolling and pitching and against the shock of recoil, the turning moment when a single gun is fired, and the shock when struck by a projectile. To reduce the friction in rising, the bearing surface must not be large, and rollers would have to be introduced to reduce this friction; and yet these bearings must form a rigid support or else the shocks and forces will affect the ram on which the system is supported, reducing its efficiency, if not destroying its action. However efficiently this difficulty may be met, the system will always be more fragile and more liable to be jammed or otherwise put out of working condition.

7. The rising will cause mechanical difficulties to be involved in the joints for the supply of power to the guns for elevating, loading, etc., for the supply of ammunition, particularly when the gun remains elevated, the transmission of power controlling the training gear and ammunition hoists, and in all other connections between the guns and the outside—difficulties in which electricity alone could avoid the undesirable features of telescopic joints.

Thus, though slightly favorable to stability and steadiness, the features inherent in the system involve complexity and liability to accident, a loss in rapidity of fire, an exposure of guns to danger from other guns on board, an increase of punishment to the hull, serious mechanical difficulties, and greater fragility or

liability to be jammed or put out of action. The gravity of these objectionable features on board ship is evident.

XIV.

The details of the features of the method proposed will not be considered at length for the reason stated in the beginning. The applicant could not have proposed any reasonable details. It would be impossible for any one but an expert to even approximate reasonable designs for the system with its complicated mechanism.

It will suffice to point out simply certain features of two sketches, Figs. 11 and 12, furnished by the applicant:—The proportions are not good; scantlings exaggerated; weight of movable parts enormous; thickness of armor fabulous. The box form of armor is inefficient and without support. It would be impossible to make armor of the form indicated and impossible to support it efficiently. It is impracticable to attempt to have two positions for disappearing; the weight of armor required would be utterly inadmissible. The only practicable form that would fulfil the idea of the form proposed, would be something like that shown in sketch Fig. 13, which represents the gun run out. No adequate method is shown or proposed for sustaining or securing the lifted weight against the friction when the guns are raised with the vessel inclined, against the inertia of rolling and pitching, against the turning moment when a gun fires, against the shock of firing and the shock when struck by a projectile. The combination of rollers and hydraulic ram presents the difficult situation that if supports are fitted to take the above forces and shocks sufficiently rigid to protect the ram from their effects, the rigidity will interfere with the efficient working of the rollers; while, on the other hand, if the rigidity or support is not secured, the forces and shocks will affect the ram.

It would be difficult, if not impossible, to pack the ram efficiently with its angular form, particularly on its inner surface, which could not be reached for adjustment; further, this form of ram entails excessive weight and is easily injured and thrown out of working order.

No system is shown or explained for transmitting power into

the turret for the purpose of elevating and loading, or for transmitting motion from the turret for controlling the training and the supply of ammunition. With the lifting movement, it is difficult to make any transfer of power or even of force or motion from the outside to the turret, or *vice versa*. As stated above, any but electrical arrangements would require long telescopic joints of difficult and more or less fragile construction.

No method of hoisting ammunition is shown or described, though the vertical movement makes this feature a difficult one with the form of ammunition tube adopted. The ammunition tube as shown is inadmissibly small.

Thus, in sum, the features of the method proposed do not face many necessary and difficult problems, theoretical and practical, involved by the system, and those that have been faced have not been solved within the remotest degree of practicability.

However, the method involves features which, in proper shape, are probably the best adapted to use on board ship, the use of a simple vertical rise accomplished by a hydraulic piston acting directly.

The simple direct rise in the disappearing mount is not new. It was employed on shore in France toward the end of the last century in a crude form where the platform carrying the gun was carefully counterbalanced and only moderate force from hand power sufficed to cause the rise through a large altitude. It has recently been perfected in France by Canet for use ashore on an armored turret raised directly by a hydraulic ram, the fall being sufficient to cause the gun-port to pass below the level of the pit over which the gun fired, the gun having recoiled till its muzzle entered the turret, whose top when down rests on the rim of the pit. It has, however, never been adopted on board ship.

A more definite idea of these two principles cited can be had from sketches Figs. 17 and 18 of a form that suggests itself for putting them in a more practicable shape.

The turret is of thin armor with sloping sides, and, like the barbette, is circular in section like the barbettes found in connection with turret guns on French battleships. The gun, the turret, and all its contents are carried on a central built-up tube somewhat similar to the tube of the Farcot system of turret adopted on French vessels, though cylindrical over a greater part of its length. The

base of the tube ends as a ram plunger in a hydraulic cylinder fitted on the inner bottom, with a stroke of 6 feet. The training gear is hydraulic, fitted as on French battleships, though the drum or band on the central tube, over which the chains reeve for revolving, carries a feathered jacket or sleeve that permits the free vertical movement of the tube, while it transmits the movement of rotation.

Separate ammunition tubes are fitted, the central tube not being used for this purpose on account of the difficulty presented by the rise. These tubes lead to the loading platform, and when it is desired to continue fire without descending to load, the ammunition is wheeled on a car around a track until it comes beneath the rear end of the gun, and from this position is hoisted into the turret by a hoist fitted to the turret cover. In the raised and trained position the weight rests on the ram. In the housed position it rests on a ring base covered by hard rubber for a buffer, supported from the armor deck in the usual way. At the passage of the central tube, through the decks and platforms there are strong roller bearings, to reduce the friction in the rise, and to offer rigid support for shocks and forces acting on the weight lifted. To this end, the accurate bearing could be insured by having the rollers on part of the circumference adjustable. A guide support, not indicated, is built around the ram just above the cylinder, to save the cylinder from strain.

The barbette is about 30′ external diameter; is self-sustaining, without backing. Gates are cut to allow the entrance of the chase of the guns in descending. These are closed by armor-doors in two sections, both sections closing when the guns are up and completely closing the gates, the upper ones only closing when the guns are down.

The weight lifted is about 230 tons. The diameter of ram is 30″. An accumulator, with air chamber, made up of tubes or pipes, weighing about 7 tons, supplying about 30 cu. ft. of water under a pressure of about 900 lbs. per sq. in., suffices to effect the rise without the assistance of the pumps. Pumps of about 90 horse-power can charge the accumulator in two minutes. Air is kept supplied by a small pump weighing about 500 lbs. The presses for training are fed from the accumulator.

It may be pointed out that the development of the disappearing

principle has been principally along the lines employing rocking shafts and levers. The early examples, covering the first half of this century, employed the principle of the eccentric and the inclined plane, but the important developments since, excepting the case of the Canet turret, cited above, have employed rocking shafts and levers in single or double pairs, actuated by counterbalance, spring, hydraulic, pneumatic, hydro-pneumatic, and hydraulic-spring power. The rocking shaft lever system has the inherent advantage of being required to lift only the weight of the gun, the recoil gear being below, associated with the raising gear and utilizing or not, for subsequent raisings, a part of the energy of recoil and descent. It has also the inherent advantage of economizing time by returning automatically at recoil to the position for loading, and by permitting the elevation and sighting from below, the gun rising to its firing position all ready for fire. In addition it throws the muzzle forward over the parapet or redoubt or turret for firing.

It is the lever form that has been adopted in all five of the systems cited, notwithstanding the fact that on board ship the unsteadiness of the platform requires the gun to remain in the firing position, personally directed by the gunner, for a period more or less extended, during which time the gun is exposed, though, as demonstrated above, this exposure is not of so great consequence, the vulnerability of the gun not being great and the probability of being hit by projectiles of large caliber being small.

If the gunner follows the gun up, which is more or less necessary on board ship, his exposure would be very great.

In connection with the disadvantage incident on board ship to the impossibility of employing satisfactorily the method of indirect sighting used ashore, on account of the unsteadiness of the gun platform, it may be pointed out that the first Russian ship to adopt the system was a coast defense vessel of the Black Sea squadron, and the three recent battleships having it all belong to the Black Sea squadron. The only vessel carrying the system on the high seas, the Temeraire, is having the guns replaced, abandoning the system, though the system was not abandoned till the guns mounted, which were muzzle loading, became obsolete.

Though it is difficult to draw exact conclusions, the fact that the experiment was not repeated on the high seas would indicate that,

on the whole, the system was not considered as entirely satisfactory for adoption on board ship.

The levers require also a large horizontal sweep which will always increase the space required for their action. In the cases thus far adopted on board ship, the guns have recoiled back entirely within the armor defense, though they cannot be said to meet the difficulty due to the great length of recent guns, for the guns on the Temeraire and the Vice Admiral Popoff are of the old short type, and those of the Tchesme and her sister ships are all six mounted in a large redoubt, where space is but a small item.

The mount of the Temeraire, outlined in sketches, Figs. 15 and 16, was the Randel system. The guns were 25-ton guns, and were raised out of towers and barbettes 7 feet high by hydraulic rams acting on bell-crank levers, no use being made of recoil energy, which was taken by usual hydraulic recoil cylinders. The rotating platforms carried the hydraulic training gear. The hydraulic pumps were below the water line, controlled from the platform. When firing against time, the interval between shots for four rounds was one and one-half minutes.

The mounts of the Russian vessels are of the Moncrieff system, simple hydraulic. An outline is given in sketch Fig. 14 of the type used on the three battleships cited above for three pairs of 12″ guns.

The hydraulic cylinders serve the double office of raising the guns and taking up the energy of recoil and descent. They work through the intermediary of a hollow plunger connected by levers with the rocking shaft.

The training gear is of the ordinary type, worked by steam. Water is supplied from an air accumulator, sufficient to raise the gun once without the assistance of pumps.

The ammunition hoist is of ordinary type, worked by steam. The guns together weigh 100 tons, and the carriage complete, including training gear, accumulator, etc., weighs 120 tons and costs about $75,000, which compares favorably with carriages for ordinary mounts. The mechanism has worked well in service. It is to be noted that the weight to be lifted is only about $\frac{3}{4}$ of the weight lifted in the proposed mount, and the rise, 4 feet, is only $\frac{2}{3}$ as great, while using the lever system avoids those serious difficulties of joints, and bearings, and supports cited above. But the guns

and gunners in the raised position are entirely exposed, and, as mentioned above, the lever system is unsuited for carrying up protection,—which is essential on board ship, except under exceptional conditions of sea, on account of the length of time it is necessary to remain in the raised position in order to sight properly, the platform being unsteady and indirect sighting being impracticable.

These three vessels realize a great saving of weight, practically the total weight of three turrets, but it may be pointed out that weight is lost in the adoption of an armored redoubt instead of barbettes, and the protection is insufficient even for the lowered position of the gun on account of the entire lack of cover, leaving complete exposure to plunging fire.

Thus, though the cases cited are interesting as examples of the disappearing principle afloat, they only fulfill the object of saving of weight and utilizing invisibility for protection, without attempting to realize any increase of angle of fire, without realizing an increase of mean security, and without attempting to realize any security for the guns in the firing position, while they throw no light of experience on the practicability of the difficult mechanical features inherent in the system. They show the practicability of employing hydraulic power, in connection with an air accumulator, to perform the work of lifting the weight; but even here, the work is only one-quarter of the work necessary in the proposed system.

SUMMATION AND CONCLUSIONS.

A.

Examination was requested on the ideas or principles involved and illustrated without reference to details. Investigation showed, however, that the entire value of the system depends on the success of method or the perfection of details, and, in consequence, it has been necessary to pass in review the main inherent features of the method, and the main features of detail proposed, in order to form a just estimate of the value of the system, and the value of the model.

B.

The examination has led to the establishment of facts as follows:

I.

1. The model, as a piece of workmanship, is in good proportion, and indicates extended thought, ingenuity, care, perseverance and patience in building.

2. The object of the system is to increase the effective power and efficiency of the main battery by increasing the effective angle of fire and the mean security of the heavy guns.

3. The main features in the proposed accomplishment of this object are the use of an unobstructed flush upper deck and the use of disappearing mounts in a form to permit fire over gun positions while the guns are below deck.

4. The second feature has not been adopted in any naval design, and, as far as research showed, has not been previously proposed.

II.

FEATURES OF A FLUSH UNOBSTRUCTED UPPER DECK.

1. The realization of this feature presents disadvantages and difficulties, the most important of which are connected with the sweeping away of mounts for guns of the secondary battery. These disadvantages and difficulties are not, however, without the possibilities of adequate remedies.

C.

Effect on Effective Power of Main Battery.

I.

EFFECT ON OFFENSIVE POWER.

Gain in Angle of Fire.—1. The possible gain is large.

2. The gain on the Iowa, by complete application, would be $\frac{1}{3}$ for the 12″ guns and double for the 8″ guns. Taking the amount of offensive energy generated as the term of comparison for two batteries, the mean gain would be .7, or the mean angle resulting would be 1.7 times the mean present angle.

Loss in rapidity of fire.—1. It is impracticable to have more than one position for disappearing. If the guns are lowered after each round, loss is incurred in lifting, in training to the bearing of fire, in training back to the position for lowering, and in lowering.

Assuming a perfected mechanism these losses would cause a loss in rapidity of fire estimated at $\frac{1}{6}$.

2. With imperfect mechanism, loss could be double the above figure or even larger.

3. The resultant effect on offensive power assuming perfected mechanism would be an increase in the proportion of 1.45 to 1. It would be less with imperfect mechanism, depending on the degree of imperfection.

II.

EFFECT ON SECURITY.

(*A*). *The Extent of the Need of Additional Protection to Heavy Guns.*

I.

PROTECTION OF HEAVY GUNS AS MOUNTED IN TURRETS OF USUAL FORM.

1. Heavy turret armor may be taken as an over match for guns.

2. The gun proper, chase and breech are but slightly vulnerable and have slight probability of being struck effectively.

3. The platform and all gear associated with it is vulnerable but runs very slight chance of being hit if doors or shields are provided for gun-ports.

4. The gun's crew is exceedingly vulnerable but runs slight chance of being hit if gun ports are protected.

5. Fixed portions, all within barbette or below protective deck, may be considered as having perfect protection.

6. On the whole, the system comprising heavy turret guns as usually mounted is well protected.

II.

THE PROTECTION OF THE REST OF THE VESSEL.

1. *Protection to Floatability.*—In a sea-way, but a small fraction of area exposed to both submersion and emersion is protected by heavy armor, and a smaller fraction by light armor. The ameliorating measures are of but slight importance, except the one of developed subdivision. Protection to floatability is inferior to protection to turret guns. Increase would take the line of increase of area of light armor and increased power of secondary battery.

2. *Protection to Stability.*—The principal factors of danger, the loss of moment of inertia of water-plane and the accumulation of

water above the armor deck, are badly exposed in a sea-way. Protection to stability is less than protection to turret guns. Increase would take the line of increase of area of light side armor.

3. *Protection Against Heel and Change of Trim* is similarly disproportionate. Consequences of same affect battery and stability and floatability.

4. *Protection of Vitals.*—Weak point; lack of an armored splinter deck. Protection to vitals is less than protection to turret guns.

Increase would take the line of fitting an armored splinter-deck.

5. *Protection to Secondary Battery and Personnel.*—Not in proportion to protection of turret guns.

Additional light armor as a remedy.

Remarks on military-tops as to the feature of being raised and lowered.

III.

SUMMATION OF RELATIVE PROTECTION TO TURRET GUNS AND TO OTHER PARTS OF VESSEL.

1. All features are less protected than turret guns.

2. It is advisable to direct effort toward an increase of the protection of weaker features.

3. The method of procedure would be an increase of the area protected by light side armor, and the working of a heavy splinter deck.

IV.

BUT SLIGHT VALUE CAN ACCRUE BY INCREASE OF TOTAL PROTECTION OF HEAVY TURRET GUNS.

Additional Protection is not Needed.—1. Guns are over-protected.

2. It would be advisable under certain conditions to have heavy turret guns on deck and invite fire on them to divert it from the hull.

(*B*). *The amount of Additional Protection to Guns Afforded by the Proposed System.*

Exposure of Heavy Turret Guns.—As at present mounted, the turret guns are very slightly exposed.

Exposure of Guns in Proposed System.—1. Exposure is reduced to zero while below deck, which position is occupied about two-thirds of the time assuming perfected mechanism; but this reduction is not great.

2. Exposure is greater while above deck which position is occupied about one-third of the time.

3. If the guns descend for loading after each round, what may be termed the mean total quantity of protection will not differ largely in the two systems. With perfected mechanism, the proposed system would realize but very slight additional protection to guns.

(*C*). *The Difference of Nature or Quality of the Protection.*

1. The protection of usual turret guns is constant.

2. The protection of the disappearing guns, remaining above deck or disappearing at will, is variable.

3. The exposure of guns will vary between large limits during all probable engagements of battleships.

4. On a vessel of war, which is entirely made up of compromises between conflicting elements, protection is best when only proportional to exposure.

5. The protection on the disappearing system proposed, varying at will, is superior in *quality* or nature to the protection of heavy turrets.

6. The feature of variability permits the adjustment of the protection of the guns in the proposed system to correspond to the protection of hull.

7. The moral effect of the protection is to the advantage of the crews of the guns of the disappearing system.

8. In sum, the variable nature of the protection in the disappearing system gives it a superiority of *quality* over the protection of ordinary turrets.

(*D*). *Results of Examination of Effect on Security.*

1. But slight advantage can accrue from *any* increase of the mean total quantity of protection to heavy guns.

2. The mean of this possible total gain in quantity of protection realized by the proposed system can be but slight, even with perfected mechanism. From the standpoint of mean total quantity of protection, but slight advantage can be realized by deviation from the usual turret mount.

3. The variable nature of the protection in the disappearing system gives it a superiority of *quality* over the protection of ordinary turrets.

4. In sum, the proposed system offers advantages for the security of the guns, but the slight advantage in possible *quantity* of protection, and the decided advantage in *quality* of protection both depend for their realization on the efficiency or perfection of the mechanism.

III.

RESULTS OF EXAMINATION OF EFFECT ON EFFECTIVE POWER OF MAIN BATTERY.

1. The offensive power would be increased in the ratio of about 1.4 to 1, with perfected mechanism.

2. The security of the guns necessary for the use of offensive power would be increased, slightly increased in quantity, and decidedly enhanced in quality, with perfected mechanism.

3. In sum, the effective power would be decidedly increased in both its elements with perfected mechanism.

4. Perfection or efficiency of mechanism is essential to both elements of increase.

D.

Various Features Influencing the Advisability of Adoption.

I.

THE QUESTION OF WEIGHT.

1. In properly designed form, there would be a gain of two-thirds the weight of the turret armor for 12″ guns.

2. A loss of about 30 tons would be incurred in increase of mechanism for 12″ guns.

3. A slight gain would be realized in weight of turret armor for 8″ guns.

4. A slight loss would be incurred in increase of mechanism.

5. The net gain or saving would amount to about 150 tons for the battery in question.

II.

FEATURES INHERENT IN THE SYSTEM.

1. The change in position of weights influences favorably, though in a small degree, the stability and steadiness of platform.

2. The system incurs danger to guns on board.

3. More hostile shots will hit; the hull will receive more punishment, though less able to bear it.

4. Complexity will be increased with increase of liability to get out of order.

5. The system is more fragile and more easily deranged or disabled.

6. Serious difficulty is involved in providing, even partially, against shocks, inertia, and deranging friction.

7. Serious mechanical difficulties are incurred in joints and fittings.

8. In sum, grave difficulties stand in the way of practicability.

III.

FEATURES OF THE DISPOSITIONS PROPOSED BY THE APPLICANT.

1. Proportions, scantlings, weights are all abnormal.

2. Barbette armor is of fabulous thickness, impossible form, and without possible support.

3. Two disappearing positions are provided; an inadmissible feature.

4. No method is shown for security against the forces of vertical friction, inertia, and shock.

5. Friction rollers requiring play are associated with a hydraulic piston requiring rigidity.

6. The form of ram is heavy, fragile, and difficult, if not impossible, to pack.

7. No method is shown of transmitting power into the turret or cage, for purposes of elevating, loading, etc., across the difficult joint between rising and fixed parts.

8. No ammunition hoist is shown, and it would be difficult, if not impossible, to fit one.

9. The ammunition tube is inadmissibly small.

10. In sum, grave practical difficulties are not faced, and the attempts to face others are all inadequate and impracticable, where not impossible, of execution.

11. The disposition involves, however, the idea of the method along which the difficulty of lifting can be best accomplished, that of a hydraulic piston acting directly to produce a simple vertical movement.

IV.

FEATURES OF THE SYSTEMS FOUND ON BOARD SHIP ABROAD.

1. *In the British Navy.*—On the battleship Temeraire. Lever system—Randel type—three short muzzle loading 25-ton guns, mounted singly, disappearing in barbettes; no increase of angle of fire; no protection in firing position; moderate weight; moderate lift; simple mechanism; long use in service; good results for rapidity of fire; example not repeated in British service; guns obsolete being replaced by modern guns of usual type.

2. *In the Russian Navy.*—Four vessels of the Black Sea squadron, three battleships and one circular coast defense vessel. Lever system—Moncrieff type—simple hydraulic in connection with air accumulator. On the battleships six 30-caliber, 12″, 50-ton B. L. R., mounted in pairs, disappearing in a single armored redoubt; no increase in angle of fire; no protection in firing position; moderate weight; moderate lift; simple mechanism; successful tests and use in service; looked on with favor.

3. All five mounts are of the lever system, which involves moderate weight to lift and simple mechanism, but is not adapted to increasing the angle of fire and the carrying of protection for the firing position. All demonstrate the efficiency of hydraulic power to accomplish the work of lifting, though the amount of work is but a fraction of the amount required by the proposed system. The systems do not seek to realize the main objects of the proposed system, and do not involve its principal inherent mechanical difficulties.

E.

CONCLUSIONS.

The facts above enumerated lead to the following conclusions:

I.

1. Realized under perfected conditions, the proposed system would materially increase the power and effectiveness of the main battery by increasing the offensive power, and by improving the conditions of security. The offensive power is increased by the increase of angles of fire, an increase which, under the conditions supposed, would largely overbalance the decrease due to loss in

rapidity of fire, while the efficiency of the security is improved by the variability of its nature, an important characteristic afloat, permitting adjustment to suit exposure, and to suit the relative protection of the hull. By regulating the extent and frequency of recourse to disappearing, the factor which enhances the angles of fire and increases the protection, but which reduces the rapidity of fire, the interdependent elements of offensive power and defense of the heavy guns can be regulated at will to suit the needs of the occasion, a valuable quality on board ship not realized in any existing system.

2. The same would realize a material saving in weight, the saving in weight of turret armor largely overbalancing the increase due to additional mechanism.

3. The same would create a moral force in its own personnel and the personnel of the enemy setting to its advantage in both cases.

4. The same would have an ameliorating effect on the stability and steadiness of gun platform slight in extent.

II.

On the other hand,

1. The power and effectiveness of the secondary battery would be reduced. Remedy would be sufficient on large displacement; it could be only partial on small displacement.

2. The realization of the advantages incident to disappearing, cited above, would entail loss in rapidity of fire. The extent of this loss, affecting the offensive power, would depend on the efficiency of the mechanism.

3. The same would cause more shots to hit, and increase the punishment of the hull, which is already underprotected compared with the heavy guns.

4. The same would cause danger to guns on board if advantage is taken of the feature permitting increase of angle of fire by firing across gun positions. This danger would be small in volley firing in which the moral effect cited would be greatest, where the fire is controlled by a single mind. It would be serious where firing was independent.

5. The system is more fragile than the usual systems, it being practically impossible to provide other than hydraulic support in

the raised position. This could be ameliorated by special provision being made to provide the training gear and the vertical bearings against the forces and shocks acting on the sustained parts.

6. The same would involve greater complexity than the usual systems, increasing the liability to derangement. The extent of this disadvantage would depend on the mechanism—being moderate for perfected mechanism but inadmissible for imperfect mechanism. It could be ameliorated by providing for abandoning the disappearing feature, if need be—the guns remaining constantly above deck.

7. The same would involve mechanical difficulties in joints and fittings, difficulties that are serious but not insurmountable.

III.

Summing up, the ideas of the system offer advantages; the principal advantages of increase in effective power of main battery and economy of weight and the incidental advantages of a favorable moral effect and favorable effect on stability and steadiness of gun platform, which would preponderate heavily over the disadvantages incurred—disadvantages of reduction of power of secondary battery, reduction of rapidity of fire of the individual disappearing guns, the increase of punishment to the hull, the increase of fragility and complexity, and the difficulties of execution—provided the mechanism for accomplishing the various operations is efficient and substantial.

The necessity of this provision is absolute; with imperfect mechanism, with slowness and uncertainty of action, the gain in effective power of main battery is rapidly undermined in both its elements, in offensive power and in efficiency of protection, while the gravity of the disadvantages increases in rapid proportion.

As to the practical features to be embodied in a system of successful mechanism some suggestions are found in the Farcot system of turret, in the disappearing mounts on the Russian battleships, and in the Canet disappearing turret for land use, but they cover but a small part of the ground; as yet no adequate design has been made or attempted.

Expert design must be entered into in full detail, and must be experimented upon before the final value of the system can be passed upon, or the advisability of its adoption fully considered.

Within the limits of this examination it may be said that the difficulties pointed out above do not appear to be insuperable, while the possibilities for usefulness are large, particularly if their full realization is rendered possible by the adoption of sufficient displacement to allow for raising to a higher degree the weaker hull protection.

But this field for usefulness lies wholly within the domain of the expert. The model is original, interesting, and suggestive, suggests the novel features and possibilities pointed out above, but its field is limited from evident necessity to suggestion alone. Detailed examination, and design, and experiment, three necessary steps between suggestion and adoption, still remain, and it would not be advisable to take them along the lines indicated by the applicant.

* * * * * * *

Attention is called to the points of professional interest which have come up.

1. The disparity between the protection of heavy turret guns and the other elements together classed as the hull. The substantial nature of the exposed part of the gun, and the slight probability of being struck effectively. The need of extending the area covered by light armor for protection to floatability, stability, and the other elements of efficiency, and the need of an armored splinter deck.

2. The grave exposure of turrets from their unprotected gun-ports. The extreme vulnerability to projectiles entering of even small caliber, and the large probability of many projectiles entering. The practicability of fitting doors or shields.

EDITOR'S NOTE.—Discussion by members is particularly requested upon this article, the same to be printed as a part of the next number of the PROCEEDINGS. Any such discussion should be in the hands of the Secretary by Dec. 10, or as soon thereafter as practicable.

PROFESSIONAL NOTES.

TESTS OF CORN CELLULOSE.

[*Iron Age, June 20.*]

The special board appointed by the Secretary of the Navy to test the Marsden American cellulose, manufactured from the pith of corn stalks, in competition with the cellulose hitherto used, which is made from cocoa fiber, were carried out at the Indian Head Proving Grounds, near Washington, last week. Two cofferdams 6 feet high, 6 feet wide and 6 feet deep, and constructed of ¼-inch steel plate with a 4-inch wood facing and 12-inch water compartments in front and with ¼-inch steel plates on the sides and back, were filled with the rival materials. The cocoa cellulose was placed in the cofferdam under pressure at a density of 7 pounds 8 ounces per cubic foot, thus requiring 810 pounds of material. The Marsden product was inserted at a density of 6 pounds 8 ounces per cubic foot, requiring less by over 100 pounds than the cocoa product. The cofferdams were placed at a range of 320 feet from the gun muzzles. The first shot was fired at the cofferdam containing the cocoa cellulose with a 6-inch gun and a 100-pound projectile, which passed entirely through the cover of the cofferdam, making an opening 7 x 9 inches. Water was turned on and in ten minutes commenced to run through the lower edge of the shot hole at an average of ½ gallon a minute. The next shot was sent into the cofferdam holding the Marsden product with the same gun and a similar projectile. The shot passed completely through, making a 7 x 8-inch hole. Water was turned on, but none went through, the material having so expanded that the inflow of water was entirely stopped. At the next test a 250-pound shot was fired from an 8-inch gun, making a 9 x 12-inch opening in the cocoa cellulose cofferdam. Water having been introduced, poured through in 37 seconds at the rate of 1 gallon a minute. The Marsden cofferdam was fired at under similar conditions, an opening 10 x 12 inches being made. Water being turned on, at the end of three-quarters of an hour none was found to have gone through. The 6-inch holes were then immersed for 2¼ hours and the 8-inch 45 minutes, when it was found that the water had only penetrated 2 feet into each shot hole in the case of the cofferdam filled with the Marsden American cellulose, while the cocoa cellulose was found water soaked in every direction in and around the shot holes. Experiments were also made in regard to the action of fire on the two products, by which the Marsden product was found entirely incombustible, while the cocoa material burned in each instance, and twice burst into flames. The official reports of the test are to be shortly laid before the Secretary of the Navy. It is thought certain that the American cellulose will in future be exclusively used in the new war ships, provided its durability is equal to that of the foreign product. This feature can only be determined by time. In point of cheapness, the American product has the advantage over cocoa cellulose.

WAR KITES.

[*United Service Gazette, May 25.*]

Major-General Lord Methuen, C. B., C. M. G., presided at the Royal United Service Institution on Wednesday last, on the occasion of Lieutenant B. F. S. Baden-Powell, Scots Guards, reading a paper giving much novel and instructive information regarding kites and their uses in war.

The gallant officer remarked that, after having tried all sorts of forms and shapes and sizes of kites, he was able to put down the following undoubted facts as the results of his preliminary labors :—(*a*) That a properly constructed kite can be made to fly in the very lightest breezes, and that, as a rule, the higher it goes the better it flies, since the wind at a height becomes steadier and more powerful as we ascend. The days on which a kite cannot be flown through lack of wind are very few. (*b*) That by fitting "side lines" to the kite it can be steered out of the wind course—that is to say, made to fly on either side of the direction of the wind, and this to an extent of at least 45 degrees (under favorable circumstances 125 degrees, or 62½ degrees on each side). A kite can thus always be made to fly over any spot within a quarter of a circle away from the wind, and as far as its string will reach. (*c*) That in an average wind, say, 12 miles an hour, a kite can lift off the ground a weight equal to about .3 lb. per square foot of area, so that a kite of 500 square feet could lift a man. (*d*) That if the string of a kite carrying a weight breaks, the kite forms a good parachute and descends gently. (*e*) The length of the string is practically unlimited, since when a kite has taken out all the string it is able to lift (which may amount to nearly a mile), the end of the string may be affixed to a second kite, and so on. (*f*) That by suitable arrangements of cords, etc., a kite may be made to fly very steadily without any possibility of its "capsizing." (*g*) That on a perfectly calm day a kite can be made to float in the air, so long as it is towed along at a rate of at least 4 miles an hour.

It may often be desirable in military operations to communicate between bodies of troops when the usual methods cannot conveniently be carried out. A post high in the air would often then be of value. It would be specially useful to columns on the march in a broken or thickly wooded country, and under such circumstances that it would be dangerous to detach signalers to outlying posts of vantage. A kite could generally be towed along with a moving column, or could be kept floating above a camp. Even at night it might be found practicable to signal with some form of lamp. With this object small kites have been flown, carrying on their strings an ordinary signaling flag, so arranged that a man holding a pole on the ground, and moving it in the same manner as a flag, causes the flag to "wag" as desired.

A kite lifting a camera high in the air can be made to hover over any given spot, more or less to leeward, and the photographs thus taken might be of the greatest value. There is practically no limit to distance to which it could be sent, and thus plans of fortifications, camps and positions might be obtained, as well as accurate surveys of the country, showing roads, rivers, railways and houses. A camera could easily be devised to take a number of different plates automatically, and by drawing in the string, or steering to one side or other, a complete survey of a large district might be effected. Its position as regards the ground would easily be found by cross bearings or otherwise.

In the same way an explosive bomb or shell could be carried up and caused to float over the enemy's head, and be discharged by time fuze, electric wire, or otherwise. The most powerful explosives could be gently lifted up, and thus a terrible engine of war contrived, so simple that it could be carried by one man, yet more destructive than the most powerful artillery. So long as a point more or less to windward of the enemy could be gained, and a sufficiency of wind existed, this terrible bird of prey might hover over the heads of an enemy ; and even if in practice the destructive results were not so great as we might expect, undoubtedly those below would feel somewhat anxious, perhaps experiencing feelings somewhat akin to those of partridges under similar circumstances. Lieut. Baden-Powell stated he had tested the principle on a small scale, using a bunch of grass (weighing 1 lb.) as a dummy torpedo, to be released by a time fuze, hung from a kite with 500 yards of string. It worked very well, and he could even answer for the moral effect

produced, as an innocent stranger happened to be passing just underneath the kite when the fatal fuze did its (would-be) deadly work.

Last year, having come to the conclusion that a kite of 500 square feet ought to be sufficient to raise a man in a fresh breeze, Lieut. Baden-Powell had a kite of that size constructed, and found his calculations accurate and expectations satisfied by seeing the junior subaltern lifted off the ground. The object of raising a man would usually be for purposes of observation, working the kite apparatus in the same way as a captive balloon. A kite apparatus which could take up a man would possess many advantages over a captive balloon.

Since an unlimited length of line can be carried by a series of kites, this principle at once suggests itself as a means of communicating with a besieged place. There seems no reason why ten or more miles of telegraph wire should not be thus supported at 1,000 feet or so in the air. All that would be necessary would be to start the kites from some point well to windward, the first kite carrying a weighted line which could be released by a time fuze, and the desired length of kite-supported wire paid out. When the first kite was over the besieged place you would wait till the time fuze had burnt out, and then "drop them a line."

A kite might be the means of raising an electric search-light, which could be directed by several cords. It might also be used for holding up an illumination apparatus for working parties at night. Another simple contrivance might prove of great value in savage warfare; namely, the hanging of a torch on the end of a wire from the kite, by means of which native houses or patches of scrub, etc., occupied by the enemy could be set on fire.

A kite, especially one fitted with guiding lines, might prove a useful means of conveying letters, etc., from one place to another, especially across rivers or other obstacles; such a kite might even be the means of supplying ammunition to the troops in the firing line, or in any detached post. There are also many other minor uses to which kites might be put—getting ropes across rivers for bridging purposes, raising flags to show the position of camps, hospitals, etc., or even drawing transport wagons when other means had failed.

At sea, kites should prove even of more use than on land. The wind there is usually more steady, and during calm weather a steamer could tow a kite beautifully. As an elevated post for looking out for enemy's ships they should prove most valuable, and for piloting the vessel in unknown waters another peculiar advantage comes in, for an observer, say, 1000 feet up in the air can distinguish objects at a considerable distance beneath the surface of the sea. Count Orloff found that from a captive balloon 1300 feet high over the Baltic Sea, rocks and sand were clearly defined to a depth of 20 to 23 feet.

For signaling, for aërial torpedoes, for carrying messages between ships, they ought to be useful, while for boat sailing dirigible kites should prove most efficient; there would be no limit to the amount of canvas carried, the boat need not heel over at all, and the wind above is always stronger than below.

SHIPS OF WAR.

ENGLAND.

LAUNCH OF H. M. S. TERRIBLE.

[*The Steamship, June.*]

On the 27th of May, H. M. S. Terrible, described as the largest and most powerful cruiser ever built for any nation, was successfully launched by Messrs. James & George Thompson, Limited, from their shipbuilding yard at Clydebank. The keel of the vessel was laid only fourteen months ago, and

the builders after the launch were warmly complimented by Mr. Dunn, the Chief Constructor of the Admiralty, upon the expeditious manner in which the work had been carried out. The Terrible shows a decided advance on her type of vessel. Her length over all is 538 feet, and between perpendiculars 500 ft., being 128 ft. more than the Blake or Blenheim, hitherto the largest vessels of the kind in the British Navy. Her breadth, 71 ft., is 6 ft. greater, and her displacement at the load draught of 27 ft. is 14,250 tons, compared with about 9000 tons for the two other vessels mentioned. She is double bottomed, and the hull is divided into no fewer than 236 water-tight compartments. In lieu of the belt of side armor, protection to the machinery and magazines and other vital portions of the ship is afforded by a strong steel arched deck, the crown of which at the center is 3½ ft. above the water-line, while at the sides the edges of the deck are 7 ft. below water level. Additional protection is derived from coal bunkers extending for the length of the machinery above the protective deck, forming, when filled, a solid belt of coal 19 ft. in thickness. The steel skin of the vessel is sheathed outside with teak planks, and a further sheathing of copper will be added after the vessel is handed over to the government authorities. A special feature of the vessel is her speed, and consequently the space devoted to machinery is very large, amounting in total to about half the length of the vessel. On trial she is expected to give 22 knots, while an average continuous sea steaming of 20 is looked for. To attain this speed the vessel is fitted with forty-eight Belleville boilers and two sets of engines of 25,000 combined horse-power. The engines are of the vertical inverted triple expansion type, each engine having four cylinders. Space is provided in the bunkers for over 3000 tons of coal. She will have four funnels. There are in the vessel six decks—the platform deck lowest of all, then the orlop deck, the protective deck, the main deck, the upper deck, and the boat deck. The platform deck, being below the protective deck, is utilized for the stowage of ammunition and torpedoes, and also the steering gear and other works essential to the fighting efficiency of the ship. Her armament will consist of two 22-ton breech-loading guns, twelve 6-in. quick-firing guns, eighteen 12-pounder quick-firing guns, and a number of smaller quick-firing and machine guns, besides four torpedo-tubes. The last mentioned are below the protective deck, and the torpedoes being discharged below water prevents the danger of their being exploded by the enemy's fire. A feature of importance is the protection afforded to the crews of the 6-in. quick-firing guns. Each of the twelve guns is mounted in an armored casemate, which is of sufficient size to contain the gun's carriage and the whole of the crew ; and the ammunition is passed into the casemate from below through an armored tube. The vessel will carry officers and men to the number of about 900.

JAPAN.

THE FUJI YAMA.

[*The Steamship, June.*]

The following particulars in reference to war vessels now under construction in this country to the order of the Government of Japan are worth notice. As far back as 1883 a first enquiry was made in this country, through Admiral Ito, the commander of the Japanese fleet in the late war with China, for the construction of two powerful armor-clads of an improved Collingwood type, limited, however, to a displacement tonnage of about 8000 tons. It being found difficult to improve upon this type of vessel with 1500 tons less weight, the limiting tonnage was increased to 10,500 tons, or equal to a vessel of Centurion type ; but the proposed new warships being required to carry a heavier armament than the Centurion, the displacement was eventually increased to

12,450 tons, the vessel to be of the Royal Sovereign type. A commission was then appointed, composed of two naval officers—Captain Kitura Yendo, naval attaché in London, and Lieutenant Yamanoutche—together with Commanders Myabara and Takayama, of the constructive department, who visited the most important shipbuilding establishments on the Continent and in America, and from their reports it was at length decided to place the order for the construction of both vessels in this country—one with the Thames Ironworks and Shipbuilding Company, and the second with Messrs. Armstrong, Mitchell & Co., of Newcastle-on-Tyne. As the two vessels are to be sister ships, the following particulars of the one now under construction by the Thames Ironworks Company, to be named the Fuji Yama, after a celebrated mountain in Japan, will apply to both. The length between perpendiculars is 374 ft., the breadth 73 ft., and the displacement 12,450 tons, giving a mean draught of water of 26 ft. 6 in., at which draught the coal carried is 700 tons, bunker capacity, however, being provided for 1200 tons. The armor belt, which is of Harveyized steel plate, the hardening of which has been greatly improved upon in this country by the firms Messrs. Cammel & Co. and Messrs. Vickers & Co., who provide the armor for these vessels, which extends for 226 ft. in length, is 18 in. thick in way of machinery and boiler spaces, and 16 in. at ends. Each vessel has two barbettes, plated with 14-in. armor, and standing upon the steel armor deck, which extends from stem to stern, and is 2½ in. thick. A screen of 6-in. armor runs across the main and lower decks to protect the guns from a raking fire, and the whole of the sides, for the length of the armor belt between belt deck and main deck, is protected by 4-in. armor on a teak backing of 2 in. The armament of each, the whole of which is to be supplied by Messrs. Armstrong, Mitchell & Co., comprises two 12-in. breech loading guns in each barbette; ten 6-in. quick-firing guns, of which four are in casemates; twenty 3-pounder and four 2½-pounder Hotchkiss quick-firing guns; together with five torpedo ejectors, one above water and four below. There are to be two military masts, with tops, to each vessel, and five search lights, and throughout they are to be internally lighted by electricity. The propelling machinery of the Fuji Yama and her sister ship is now under construction by Messrs. Humphreys, Tennant & Co., of Deptford, and will consist of twin-screw three cylinder triple-expansion engines, designed to develop 14,000 indicated horse-power with moderate forced draught. The boilers for supplying steam will be ten in number, of the four furnaced cylindrical type, worked at a pressure of 155 lbs. per square inch. Notwithstanding the great pressure which was exerted in Tokio to obtain permission for other firms to compete for the construction of the Fuji Yama and her consort, the two above-mentioned were the only ones invited to tender for these vessels. The construction of the Fuji Yama is being rapidly proceeded with. The side armor is partly rolled, and will be delivered shortly at the works. The original time for completing was four years, but now the time has been reduced by arrangement to three years. The vessel has been designed by Mr. Geo. C. Mackrow, naval architect to the Thames Ironworks.

BOOK NOTICE.

NAPOLEON BONAPARTE'S FIRST CAMPAIGN, WITH COMMENTS. By Herbert H. Sargent, First Lieutenant Second Cavalry, United States Army.

Lieutenant Sargent makes no apology for presenting anew a much written subject, but, when the book is read, one will truly admit that no apology is needed. Confining himself admirably to the strategy of the campaign, the author treats each successive stage in a separate chapter, closing each chapter with carefully considered comments, and completing his task with a final chapter of general comments on the whole. The freedom from collateral detail and the vigor of this strategic narrative, combined with simple commentaries applying to it the principles of the art of war, cannot fail to convert its most casual reader into an interested student.

The maps, two in number, are poorly drawn. The final chapter of general comments could be advantageously condensed. The author makes occasional allusions to "the French eagles" and "the eagles of Napoleon," overlooking the fact that the eagle as an emblematic bird was unknown to France and unthought of by Napoleon until several years later. These are trivial shortcomings, and the general reader, as well as the military student, will lay aside this book feeling glad that he has read it, and with the reassurance that the officers of our army, even when stationed at isolated posts where libraries are meagre and frontier life is arduous, are carefully studying the campaigns of the great military masters.

J. M. E.

BIBLIOGRAPHIC NOTES.

AMERICAN.

ARMY AND NAVY REGISTER.

The Infantry Drill Regulations. The Manual of Arms adapted to the Magazine Rifle Caliber .30.

To insure uniformity of practice in the manual of arms for the new Army rifle, the War Department has made many modifications in manuals formerly used. The new manual is to govern the Army. It will be of great interest to national guardsmen, as the different states will also use the work. The *Army and Navy Register*, of Washington, D. C., has issued the manual in pamphlet form, the price of which is 15 cents per copy. A recent law prohibits the War Department from printing over 1000 copies of any document, which will limit their distribution to only a few in the Army.

THE AMERICAN ENGINEER AND RAILROAD JOURNAL.

JUNE, 1895. Some Facts Relating to Certain Types of Water-Tube Boilers. The Curve of Least Resistance in Water and in Air.

JULY. Method of Taking Cost Test and Chilling Points of Oils, and Other Liquids. The Proposed French Captive Balloon. High Balloon Ascensions.

AUGUST. Tubulous Boilers in the French Navy. The Economy of Steam Jackets and Superheated Steam. Third-Class Torpedo Boat for U. S. Cruiser Maine. The Proximate Analysis of Coal. The Fuse for the Pneumatic Dynamite Guns (illustrated). Aeronautics; Speed in Migratory Flight of Birds; Velocity of Air Currents.

The author measures cloud velocities, determining the position of a cloud by suitable theodolites at the end of a 1178 meter base line. He then calculates the mean cloud velocities, and from these latter states that for high altitudes (above 200 meters), in the same season, the increase of velocity is regular and uniform; that is, is proportional to the increase in height.

CASSIER'S MAGAZINE.

Niagara Power Number. Tesla Motors in a Great Manufacturing Establishment. The Use of the Niagara Water Power. Mechanical Energy and Industrial Progress, by W. C. Unwin.

Distribution of the Electrical Energy from the Niagara Falls, by S. Dana Greene, Electrical Engineer.

A number of other articles bearing upon the Niagara Falls and their power; articles, historical and scientific, beautifully illustrated, accompany those mentioned. The number, devoting two hundred and twelve pages to its subject, will have to be seen to be appreciated.

JUNE. The Care of Steel Ships, by Philip Hichborn, Chief Constructor U. S. N.

The author advocates the sheathing of ships' bottoms.

Some Recent Machine Tools. The Maximum Possible Efficiency of Galvanic Batteries. Philip Hichborn (a short biographical sketch, by Robert Gregg Skerrett). Electricity for Marine Propulsion. Solid Force Transmission.

IRON AGE.

JUNE 13, 1895. Centrifugal Pumps for United States Dry Dock.

JUNE 20. Tests of Corn Cellulose. Test of Maxim Machine Gun.

The Maxim rapid-fire single barrel machine rifle for infantry use, which was the type used in these tests, has a caliber of 0.303. The cartridges are 2.8 inches in length. The range of the gun is 3200 yards. Smokeless powder is used, giving a muzzle velocity of 1850 feet per second. The gun weighs 25 pounds when placed on its iron stand, ready for action. When taken apart and packed with ammunition and extra equipment, its total weight is 45 pounds; so that it can be readily carried by one man. Its average capacity is 500 shots a minute.

The first test was one of 50 rounds, which were fired in 5⅜ seconds. The time for unloading the gun from the knapsack to the time when the last shot was fired was 57¼ seconds. The next test was one of time. A shot was fired, the gun barrel removed, another barrel taken from the knapsack and inserted, loaded and fired within one minute and 12 seconds.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

JULY, 1895. Discipline. An Antiquated Artillery Organization. Martial Law and Social Order. Recruiting and Training of the Company. Our Artillery in the Mexican War. A Technical Criticism of Our Infantry Drill Book. Reprints and Translations.

JOURNAL OF THE UNITED STATES ARTILLERY.

APRIL, 1895. The Resistance of the Air to the Motion of Projectiles as Influenced by the Shape of the Head, by Capt. Jas. M. Ingalls, First Artillery, U. S. A. Trained Artillery for the Defense of Sea-Coast Forts. Range and Position Finding. The Uses of the Artillery Fire Game. Coast Artillery Fire Instruction.

JOURNAL OF THE FRANKLIN INSTITUTE.

JUNE, 1895. The Nicaragua Canal. Lightning Arresters and Why they Sometimes Fail.

JULY. An Apparatus for Experimenting with the Laws of Flexure of Beams. The Theory of the Air Lift Pump. Cellulose Protection for War Vessels and for the Merchant Marine. Reasons for Predicting the Existence of Argon.

SCHOOL OF MINES QUARTERLY.

APRIL, 1895. Modern Calorimeters and their Use. Argon. Chloride of Silver as an Anti-Friction Metal.

FOREIGN.

ENGINEER.

VOLUME LXXIX., No. 2053, MAY 3, 1895. The United States Naval Gun Foundry at Washington, D. C. H. M. S. Royal Arthur.

MAY 10. The Story of Ship-Building on the Tyne. The United States Naval Gun Factory at Washington D. C. (concluded).

MAY 17. The Stability of French Armored Ships. Launch of a New First-Class Battleship (the Renown).

MAY 24. Torpedo-Boat Destroyers. H. M. S. Terrible. Face Hardened Armor, by Lt. A. A. Ackerman, U. S. Navy.

A review of the article published in No. 73, Proceedings U. S. Naval Institute.

MAY 31. The Launch of H. M. S. Terrible. Armor Plate Tests.

JUNE 7. British Fuses for Modern Guns. Instability in Ships of War. Coal Consumption on Torpedo-Boats.

A correspondent of the *Glasgow Herald* states that the torpedo-boat destroyer built by Messrs. Thornycroft on a three hours' run maintained a speed of 27.97 knots—practically 28 knots—or for the whole time 84 nautical miles; and burned in her three water-tube boilers 17¼ tons of coal. The rate of combustion is 68 lbs. of coal per square foot of grate area per hour, although in some trials it has reached 79 lbs.; but then the power per square foot of grate area is very high, 24 indicated horse-power. The boats of this class carry 60 tons of fuel at a pinch, and this would enable them to go at full speed for a period of over nine hours, during which they would travel fully 250 nautical miles. The coal consumption is equal to 4 cwt. per sea mile; that is to say, during the 2 min. 9 sec. taken to a sea mile 4 cwt. of coal are burned. A ton of coal, therefore, takes the boat five sea miles. But it would only be on a rush that such speed would be maintained. Now, other tests have been made at about half the speed—13 knots—and here, instead of five miles, the ton of coal carried the destroyer for a distance of about 38 nautical miles, so that the total distance at 13 knots with the 60 tons of coal would be nearly 2000 miles. This shows the great cost of doubling the speed. The coal per horse-power at 13 knots was 1.61 lbs.

JUNE 14. The Baltic Canal.

JUNE 21. The Cost of Warships (with table in some detail). On Coupling Boilers of Different Systems.

JUNE 28. The Cost of Warships (concluded). Small-Arm Ammunition. On Water-Tube Boilers.

JULY 5. A New Departure in Steam Engine Economy. New Method of Fitting Shell and Deck Plating in Ships.

ENGINEERING.

VOLUME LIX., No. 1528, APRIL 12, 1895. The New Nordenfelt Guns (concluded). The Institution of Naval Architects. An Aluminum Torpedo-Boat. H. M. Torpedo-Boat Destroyer Ardent. The Propelling Machinery of H. M. S. Magnificent. Our Battleships, by Sir William White, K. C. B. On Solid Stream Forms, and the Depth of Water Necessary to Avoid Abnormal Resistance of Ships, by Naval Constructor D. W. Taylor. Induced Draught.

APRIL 19. The Institution of Naval Architects. Naval Works. On the Vibration of Ships and Engines. On Vibrations of a Higher Order in Steamers, and on Torsional Vibrations.

APRIL 26. The New British Cruisers. On a Method of Preventing Vibrations in Marine Engines.

MAY 3. The Institution of Mechanical Engineers. Quadruple Flashing Dioptric Apparatus. Water-Tube Boilers in Parliament.

MAY 10. The Economics of Coal. Heat Engines. Electric Welding for Repairs.

MAY 17. Japanese Shipping. The Development of Naval Ordnance.

MAY 24. The New British Cruiser Terrible. The Borchardt Repeating Pistol. Torpedo-Boat Destroyers.

MAY 31. The New British Cruiser Terrible (continued).

JUNE 7. Gunnery Trials of the Infanta Maria Teresa.

JUNE 14. The Institution of Naval Architects (Paris Meeting).

At this meeting was read a paper entitled *M G* Meter. In it the author, Mr. Archibald Denny, described an instrument which had been devised for the use of masters of vessels, so that they might obtain the metacentric height of a vessel. It consisted essentially of a spirit level pivoted at one end, and adjusted at the other by means of a micrometer screw. By the aid of a diagram the value *M G* is ascertained in a way set forth by the author.

JUNE 21. The Amplitude of Rolling on a Non-Synchronous Wave, by Emile Bertin. On Wood and Copper Sheathing for Steel Ships, by Sir William White, K. C. B.

JUNE 28. The New British Cruiser Terrible (concluded). On Wood and Copper, etc. (concluded).

JULY 5. The Measurement of Pressures by the Crusher Gauge.

In a recent communication to the Royal Society, Messrs. W. Kellner and W. H. Deering describe a series of experiments on crusher gauges. The gauges in question were of the usual form, and each was constructed of a small cylinder of copper .5 in. long and .326 in. in diameter, inclosed in a small steel cylinder, fitted with a steel ram .461 in. in diameter. One end of this ram rested on the copper rod, whilst the other was exposed to the pressure to be measured. These pressures were generated by firing cordite in closed explosive vessels of steel, having a capacity of about 120 cubic centimetres. The vessels were closed by screw stoppers, which were about 4 in. long, and were drilled axially with a ¼ in. hole. The mouth of this hole was closed by a hardened steel ball ½ in. in diameter, which could be loaded with any desired weight, thus forming a valve. By means of this device an independent measure of the pressure inside the vessel could be obtained, since, if the valve did not lift, the pressure inside must have been lower than that corresponding to the weight on the ball. The effective area of this valve was very carefully measured. By planing off a short length at the top of the plug, a new seat could be obtained for the valve when required. The weights of cordite fired were increased by short steps till a point was reached at which the gases resulting from the explosion were blown out, and the pressure thus obtained was compared with the indications of the crusher gauge. The general result arrived at was that the pressure, as estimated by the crusher gauge, was invariably too low, being about 11 per cent. wrong at pressures of 6 tons per square inch, 9 per cent. wrong at pressures of 13 tons per square inch, and 11 per cent. wrong at 16 tons per square inch.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

MAY, 1895. Gold Medal Prize Essay. Lessons to be Derived from the Operations of Landing an Expeditionary Force on an Enemy's Coast in Past Wars. A Few Practical Hints on the Working and Use of Maxim Guns. Field Artillery Fire and Okehampton Experiences.

JUNE. The Antarctic Expedition from a Naval Point of View.

JULY. Landing of Expeditionary Forces On Ship Ventilation as a Department of Naval Hygiene. Economical Army Reform, by Captain F. N. Maude, late R. E.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

MAY, 1895. Proposed Slide Rules for Calculating Battery Commanders' Corrections.

The corrections referred to are those necessitated by the movement of the target after the range has been found.

Co-operation Between Guns and Cavalry. Diary of Lieutenant W. Swabey, R. H. A., in the Peninsula.

JUNE. Terrestrial Refraction and Mirage. Diary, etc. (continued).

STEAMSHIP.

JUNE, 1895. First-Class Battleship Fuji Yama. Launch of H. M. S. Terrible. Corrosion of Boilers and Steamships. Launch of First-Class Battleship Renown.

JULY. Hydraulic Machine Tools. Cost of H. M. Vessels.

UNITED SERVICE GAZETTE.

No. 3253, MAY 11, 1895. The Genesis of English Naval Power. The Advance in the Organization and Efficiency of the Royal Naval Reserve.

MAY 18. Torpedo-Boat Destroyers. Ship Ventilation. Physical Training in the American Army, I.

MAY 25. War Kites. The Times and the War Office, III.

JUNE 1. Physical Training in the American Army, II.

JUNE 8. The Objects of the Navy League. Physical Training in the American Army, III. The Training of Naval Acting Sub-Lieutenants.

JUNE 15. Commerce Protection in War Time. The Effect of War on Our Mercantile Marine. Moral Effect in War.

JUNE 22. Military Reform. The Imminence of War.

A synopsis and endorsement of Assistant Naval Constructor Hobson's article on the "Situation and Outlook in Europe," in No. 74, Proceedings U. S. Naval Institute.

JUNE 29. Water-Tube Boilers. Parliament and the Defense of the Country. Our Own and Foreign Warships.

JULY 6. The Armament of Warships. J. H. G.

LE MONITEUR DE LA FLOTTE.

No. 15, APRIL 13, 1895. The Law in Regard to Promotion in the Navy. Something More About Running Lights.

No. 16, APRIL 20. Remarks on the Law of Promotion.

No. 17, APRIL 27. One Point in History. Voyage of the President of the Republic.

No. 18, MAY 4. The Mediterranean Postal Service. A Magnetic Map of the Globe. The Extraparliamentary Naval Committee.

No. 19, MAY 11. Speed Trials. The Extraparliamentary Naval Committee.

No. 20, MAY 18. The Working by Hand of Heavy Caliber Guns.

No. 21, MAY 25. Armor and Projectiles. Loss of the Torpedo-Boat 20. The Accident on Board the Amiral Duperré.

No. 22, JUNE 1. About the Combat of Ya-Lu.

A brief summary of facts that were demonstrated in this memorable action.

Nos. 23 AND 24, JUNE 8 AND 15. The Congress of Naval Architects. What About Cellulose? The Navy Estimate for 1896.

No. 25, JUNE 22 AND JUNE 29. At Kiel. The Extraparliamentary Naval Committee. The Naval Manœuvres of 1895.

No. 27, JULY 6. Privateer Cruisers (commerce destroyers).

REVUE DU CERCLE MILITAIRE.

Nos. 14 AND 15, APRIL 6 AND 13, 1895. The English Military Recruiting System. Madagascar. The 13th Army Corps in the War of 1870 (map). The Spanish in Cuba.

Nos. 16 AND 17, APRIL 20 AND 27. The Folding Bicycle in the Army. English Recruiting (continued). The 13th Army Corps, etc.

No. 18, MAY 4. Simple Chat on Aërial Navigation (see No. 17). Instructions of the Emperor of China to his Army.

No. 19, MAY 11. A Comparative Study of Service Small Arms.

No. 20, MAY 18. The Artillery Combined with the Other Arms.

No. 21, MAY 25. The Meldereiters of the German Army. The Artillery Combined with the Other Arms (continued). The Pneumatic Gun in the United States.

No. 22, JUNE 1. The Dutch Colonial Troops; Notes Relative to the Dutch-Indian Army. The Artillery Combined, etc. The War Budget of 1896.

No. 23, JUNE 8. The Daily Ration of the Italian Sailor. The Dutch Colonial Troops, etc.

No. 24 AND 25, JUNE 15 AND 22. The Navy Appropriations for 1896. The Preliminaries in the Madagascar Expedition. The Dutch Colonial Troops. The Artillery Combined with the Other Arms (end).

No. 26, JUNE 29. To the North Pole in a Balloon. The Dutch Colonial Troops (continued).

REVUE MARITIME ET COLONIALE.

MARCH, 1895. The Volta in China and Tonkin (1883-1885) (ended). Naval Warfare (an analysis of the work of Rear-Admiral Colomb). A Note on the Attack on the Brazilian Armored Battleship Aquidaban by the Government Torpedo-Boats, on the Night of the 15th of April, 1894. Description and Working of the Hydraulic Apparatus of the Gun of 340 mm., Model 1887. A Report on the Process to be Employed in Discovering Fraud in Table Oil and Oils Used in Manufactures.

APRIL. Naval Warfare (an analysis of the work of Rear-Admiral Colomb). Description and Working of the Hydraulic Apparatus of the Gun of 340 mm., Model 1887. Geometry of Diagrams (continued).

SOCIÉTÉ DES INGÉNIEURS CIVILS.

MARCH, 1895. Congress of Naval Engineers at Chicago. Analysis of the Statistics of Coal Mines in France. Seisms and Volcanoes.

APRIL. The Electric Cranes of the Port of Havre. A Note on the Mishap of the Steamer Gascogne. Public Aids in France and Other Countries.

MAY. Establishment of Pensions in Favor of Miners by Mining Companies.

LE YACHT.

No. 891, APRIL 6, 1895. The Colonial Troops and the Navy Ordnance Department.

No. 892, APRIL 13. The Navy in the Senate. The Protected Cruiser K. and K. Maria-Theresa.

No. 893, APRIL 20. The Wei-Hai-Wei War Operations. The German Armored Battleship Wörth.

No. 894, APRIL 27. The Peace Between China and Japan. The President of the French Republic at Havre. Admiral Galaches' System of Running Lights. The Trials of the Friant.

No. 895, MAY 4. The New Italian Naval Constructions.

On the stocks at Venice is the armored battleship Ammiraglio Saint-Bon; at Castellamare the Emanuele Filiberte; these are sister ships. Two types of armored cruisers are being built: to the first belong the Carlo-Alberto at Spezia, and Vittor Pisani at Castellamare. To the second type, the Garibaldi at the shipyards of Ausaldo at Sestri Ponente, and the Varese at the Orlando ship yards at Leghorn. The last two are somewhat larger than the first. Besides two protected cruisers, the Puglia at Tarenta, and the Elba at Castellamare, Italy has in construction several vessels of inferior rate.

The Third-Class Japanese Cruiser Suma, Built at the Government Docks at Yokosuka.

No. 896, MAY 11. The English Navy. The Institute of Naval Architects. The Multitubular Boiler in the House of Commons (E. Weyl). The New Constructions in Italy. The German Armored Coast Guard Vessel Siegfried.

No. 897, MAY 18. Creation of a Bureau Technique in the Navy. Russian Cruisers Building at Havre.

REVISTA TECNOLÓGICO INDUSTRIAL.

APRIL, 1895. The Installation of Transmission Power by Electricity at the Niagara Falls. Acetilene: Its Commercial Manufacture by Electricity; Its Adaptation to Lighting and the Carburation of Coal Gas.

MAY. Improvements in the Manufacture of Bone Gelatine and Glue.

JUNE. Acetilene, etc. Scientific Industrial Excursion of the Association of Industrial Engineers of Barcelona During the Month of June, 1895.

REVISTA MARITIMA BRAZILEIRA.

FEBRUARY, 1895. Autobiography of a Whitehead Torpedo. Reorganization of the Brazilian Navy. The Practice Ship Benjamin Constant. Torpedo-Boat Destroyers.

MARCH AND APRIL. Autobiography, etc. Reorganization of the Brazilian Navy. Pyrotechny. Smokeless Powder. Report of Engineer Antonis Perraz of the Brazilian Navy.

BOLETIN DEL CENTRO NAVAL.

VOLUME XII., JANUARY AND FEBRUARY, 1895. Brief Historical Notes on Naval Warfare, by Lieut.-Comdr. Silveyra. Steel for Ordnance.

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ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

VOLUME XXIII., No. 3. Sailing Directions for the Cameroon Coast. The Journal of Capt. Scheder, Commanding the Corvette Bussard. Circumnavigation of the Island of New Hanover. Remarks on the Description of the Coast of Annam. The Gale of Dec. 22, 1894. The Ex-Meridian Treated as a Problem in Dynamics, H. B. Goodwin, M. A. Hygienic Meteorology. Bottle-Posts. Receipt of Meteorologic Journals at the German Naval Observatory in February, 1895.

No. 4. From Honolulu to Yokohama. Cruising among the Samoan Islands. Failure to locate Colonia Shoal; Approaching Samana Bay (sailing directions). Hydrographic Conditions of Esmeralda River and the Anchorages at its Mouth. Currents along the East Coast of Africa, between Cape Guardafui and Zanzibar, during the Southwest Monsoons. Wind and Weather in the Antarctic Ocean South of Cape Horn, 1893 to 1894. On the Computation of Nautical Astronomical Problems with Four-Place Logarithms. The Coast Climate of Ecuador. Minor Notices: Shoal on Campeche Bank; Yellow Fever at Sea; From Apia to Auckland; Soundings in the Harbor of Newcastle, N. S. W.

No. 5. From Valparaiso to Puerto Montt. Water Temperatures on a Trip from Chefoo to Chemulfo and Back. Experiments on Smoothing the Sea with Soapy Water. A Trip up the Yang Tse Kiang, and a Description of Three Typhoons. Aroe Bay, Sumatra. Report of the German Naval Observatory on Results of Magnetic Observations Along the German Coast, During 1894. Balloon Ascents to the Regions of Cirrus Clouds. Studies on Fog Signals. Transparent Diagrams of the Atmospheric Movements During Cyclones and Anti-Cyclones. Meteorology of Purdy Islands. Notices: A Danish Expedition for Exploring the Waters of Greenland.

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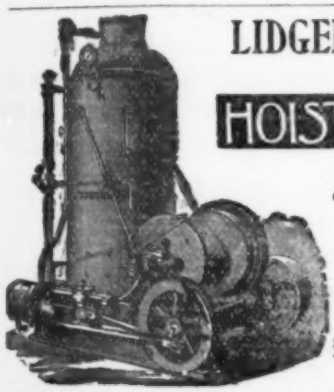

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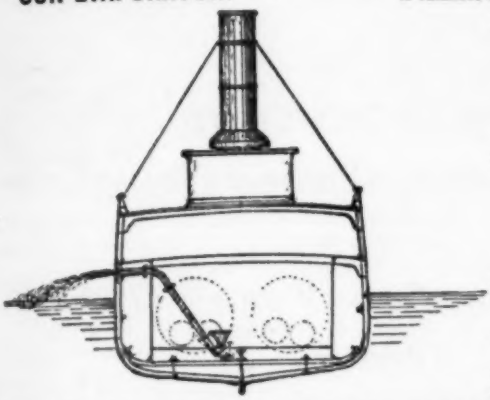

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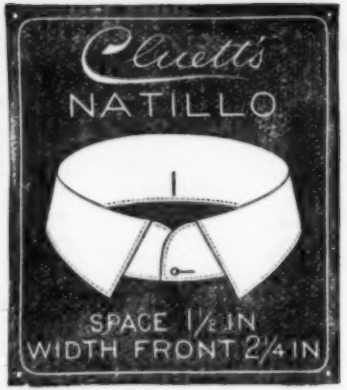

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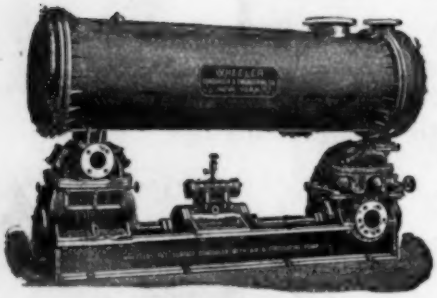

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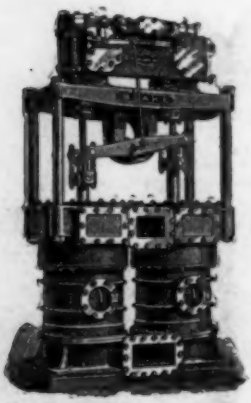

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